LABORATORY ARTS

G. H. WOOLLATT

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A TEACHER'S HANDBOOK

DEALING WITH

MATERIALS AND TOOLS USED IN THE CONSTRUCTION, ADJUSTMENT, AND REPAIR OF SCIENTIFIC INSTRUMENTS

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WITH 119 DIAGRAMS

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PREFACE

THIS book is intended for the teacher who is more or less in charge of the apparatus he uses. The necessity for ability and skill in repairing or readjusting instruments of all kinds is evident to any science teacher who has conducted a year's experimental work; and it is hoped that sufficient information and instruction are contained in the following pages to enable a teacher not only to acquire this necessary skill, but to turn it to account in the making of simple laboratory apparatus, and in the construction of new forms of apparatus and teaching devices.

The ability to "fix up" a piece of uncatalogued apparatus, by which a point under discussion may be proved, is worth the expenditure of time and trouble in its attainment, but until now no systematic attempt has been made in this direction, and it is only through the organization of summer courses for science teachers in Ireland and Yorkshire that the prospect of success is held out. The present book has been written upon the basis of experience obtained in the conduct of the above summer courses, and though incomplete, and doubtless full of imperfections, it should enable any searcher to obtain sufficient assistance to be able thence to help himself.

Many of the methods recommended here are not trade methods. Some are superior, inasmuch as the question of

time-cost is not so important as that of the perfection of the product; while some are inferior, in consequence of the limitations of skill, tools, etc. It would not be expected, *e.g.*, for a teacher to weld the two pieces of a broken steel pin or shaft, though possibly this would make the best job. He has to be content with half-lapping, drilling, and riveting, which are processes entirely at his command. Similarly, it is not necessary from a carpenter's point of view to include the tongue in the back bracket of the Hare's apparatus on page 19; but this is inserted (1) as an exercise, (2) in order that the ordinary shaky construction of the amateur may be stiffened—extra strength of design being made to take the place of skill in construction.

The craftsman will doubtless find humour in some of the suggestions put forward herein, but it should be remembered that we are first of all teachers, and that we must use skill in craftiness in order to overcome our lack of the craftsman's skill. These are methods that will serve our purpose, and they are within our resources.

The professional apparatus maker will have no cause for alarm, rather will he be gladly rid of the many repairs that fall to his lot from time to time, and are so unsatisfactory. The teacher will henceforth pull down his "repairs," in order to learn the principles of construction, and buy a new apparatus! He will no longer blame the professional repairer, for having seen the hopelessness of some of his own efforts, he will respect more fully the new apparatus, and protect it from damage with greater assiduity; and, knowing more of the principles of construction, will be the less likely to put his apparatus to undue strain.

In addition to the difficulties of construction and repair, there are endless problems which worry the teacher in charge of laboratory work. The cleaning of mercury, the re-silvering of a galvanometer mirror, the loosening of burette stoppers, are details which are almost constant sources of trouble and annoyance to the teacher, and of loss of time to the class. The removal of these must make for increased efficiency and more comfortable teaching conditions, and it is hoped that the fourth section of the book will do much toward this desired end.

It is hoped also that the exercises given in this book may be of use to those teachers who wish to make a practical contribution to the co-ordination of manual training and science. All teachers know the difficulty of finding interesting exercises in manual work for boys, and simple apparatus lends itself remarkably well to this end. Model turbines, wheel barometers, steam heaters, steam and water jackets for eudiometers, etc., are well within the possibilities of an ordinary schoolboy after two or three years at manual training in wood and metal, and the equipment of a laboratory may be materially strengthened by a co-ordination between these departments, without detriment to the educational value of either—indeed, with positive profit to both.

It may be stated that the present volume is written without extensive reference to contemporary text books. It is placed upon the market as a record of the author's experience during some twenty years of practical laboratory teaching in almost all grades of educational endeavour, and it is hoped that it may be accepted in that light. Other methods than those herein described exist; other processes give excellent results. The

present volume is intended simply to place at the disposal of all science teachers an experience gained at considerable cost, both in time and trouble, and to aid a teacher who has original methods of teaching science and who wishes to present his subject in as fresh and personal a way as possible, to overcome the mechanical difficulties that at present hinder the realization of his desires. It is hoped that the brotherhood of science teachers will accept this effort in such spirit, that they will criticize where necessary, and so help in the production of a more useful volume, and consequently to an enhanced efficiency of science teaching. No mere book-work can completely fulfil the purpose for which this volume is designed, particularly in the case of glassworking, which is mainly a matter of experience.

All science teachers should go through a course of practical work in at least the three principal materials considered in this book—a few minutes' instruction, and the supervision and criticism of work by an expert while it is progressing being worth hours of patient research upon the bench, and being far less destructive to one's patience. Courses of this character are now organized in Ireland by the Department of Agriculture and Technical Instruction, and in England more recently by the Educational Handwork Association, in each case at times and centres convenient of access to teachers, and indications exist that other progressive educational bodies are about to follow upon similar lines. The result must be a quickening of interest on the part of teachers able for the first time to construct their own special apparatus, and therefore encouraged to research upon new methods of demonstration; at the same time a material reduction of the cost of repairs

to apparatus and a better condition of that already in use should transpire.

No directions are given for the adjustment of specific instruments; attention has rather been paid to the acquirement of skill in handling tools, and to the attainment of a knowledge of the principles of construction, as with these assets any ordinary teacher should be able to discover the "fault" and amend it.

I have to thank my friend and assistant Mr. James A. Wightman for valuable help both in the text and in the work of seeing the volume through the press. Acknowledgments are also due to Messrs. Woolley, of Manchester, Herr Julius Springer, of Berlin, and Messrs. Longmans, Green & Co., from whose publications some of the figures and tables in Appendix III. are quoted.

G. H. W.

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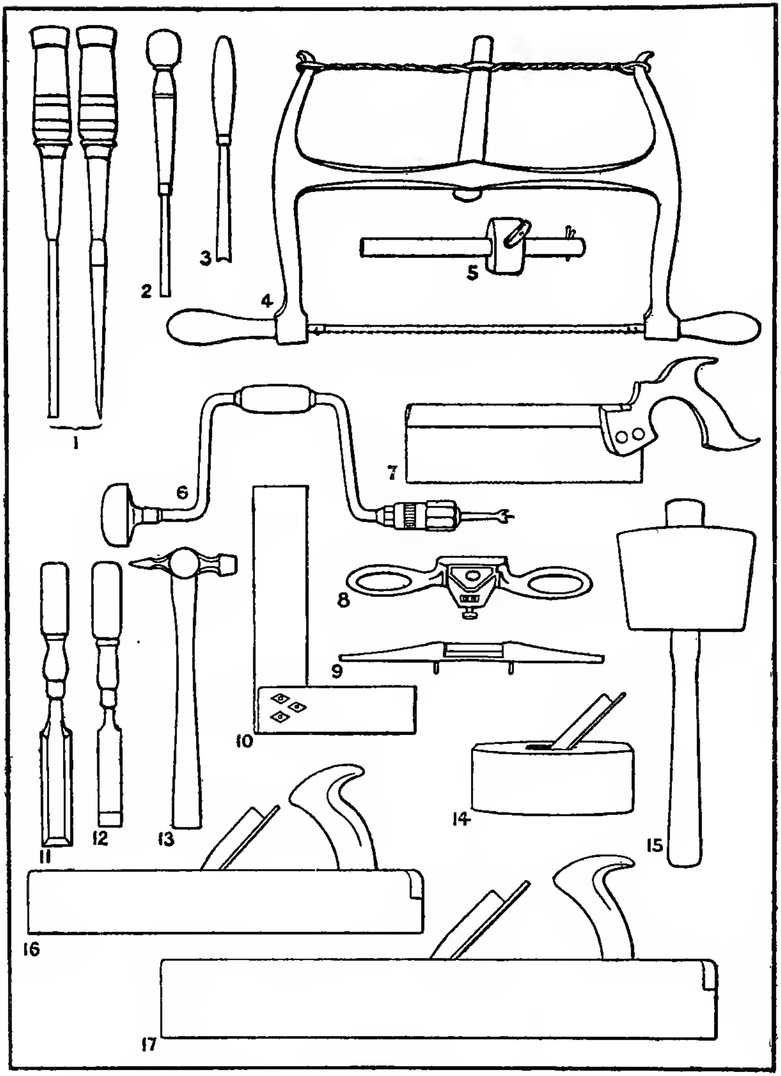


PLATE I.

Woodworking Tools, Drawn to $\frac{1}{8}$ Scale.

1. Mortising chisel.
2. Turnscrew.
3. Gouge.
4. Bow saw.
5. Marking gauge.
6. Brace and bit.
7. Tenon saw.
8. Iron spoke shave.
9. Wooden spoke shave.
10. Trysquare.
11. Firmer chisel (ground edges).
12. Firmer chisel (ordinary).
13. Hammer.
14. Smoothing plane.
15. Mallet.
16. Jack plane.
17. Trying plane.

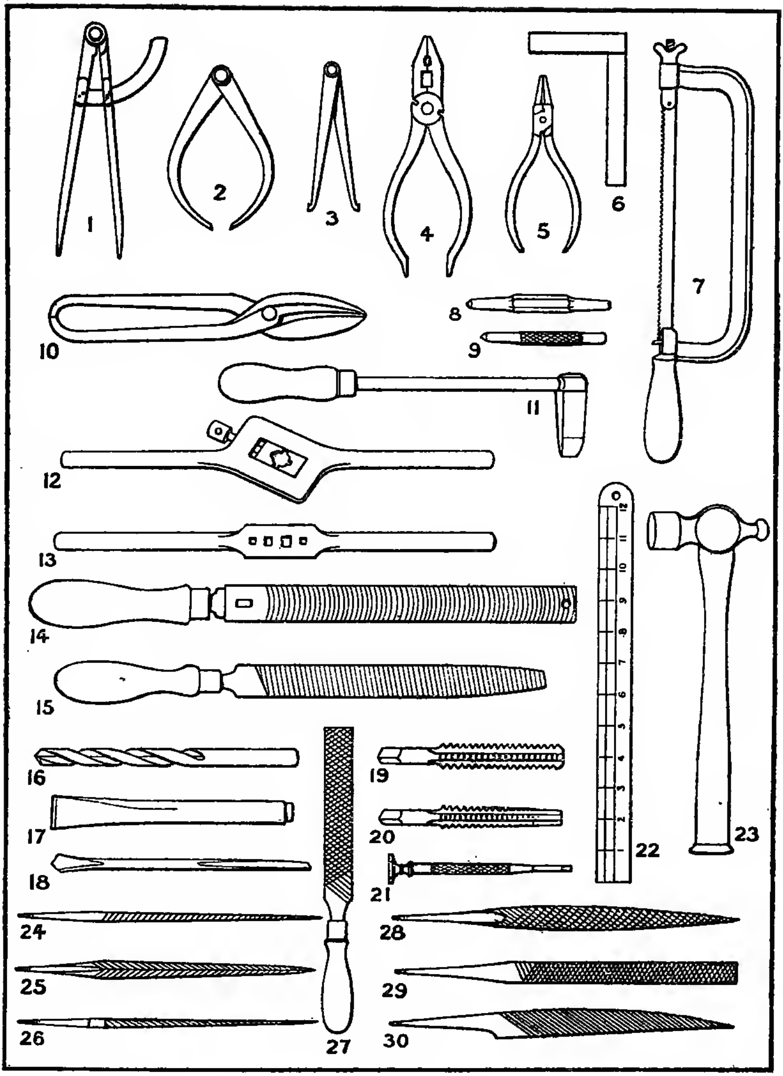


PLATE II.

METAL WORKING TOOLS, DRAWN TO $\frac{1}{6}$ SCALE.

Nos. 24–5–6, and 28–9–30—a set of small files—are drawn to $\frac{1}{3}$ scale.

1. Compasses.
2. Outside callipers.
3. Inside callipers.
4. Square-nosed cutting pliers.
5. Taper-nosed pliers.
6. Trysquare.
7. Hack saw.
8. Centre punch.
9. Dot punch.
10. Snips or shears.
11. Soldering iron.
12. Stock and dies.
13. Tap wrench.
14. Milling file.
15. Half round file.
16. Twist drill.
17. Chisel.
18. Wing drill.
19. Plug tap.
20. Taper tap.
21. Turnscrew.
22. Scale.
23. Engineer's hammer.
27. Cross cut file.

LABORATORY ARTS

SECTION I

WOODWORKING

I. Timbers.

The principal woods used in instrument making are: "Bass" wood (American white wood or canary wood), yellow pine, mahogany, beech, teak, ebony, and box. Less common ones are: Sycamore, holly, "black" walnut, satin walnut, and oak.

These woods are chosen apart from any consideration of cost on account of certain definite characteristics which are dealt with below. The cost is not taken into account, because—

1. The quantity of wood used is generally small.
2. The value of the wood is very small in proportion to that of the instrument.

For each specific purpose in instrument making there is one wood that is most suitable, and this should always be used.

Timber used in apparatus making should always be excellently seasoned, free from knots, shakes, and sap wood. The finest quality only should be used, save for the erection of heavy mechanical apparatus.

Bass Wood.—A soft, light-coloured wood, varying from pure white to green, with black knots. The wood is porous, easily worked, and takes stains, varnishes, and polishes remarkably well.

If sound and well seasoned, it retains its form admirably, but it is rather subject to dry rot, and frequently an unfair proportion of sap wood is included in boards.

Its cheapness, the ease with which it is worked, and the

certainty of being able to obtain it quickly in any required width and thickness, cause it to be the staple material for the construction of stands, boxes, cases, covers, and all appliances which do not involve delicate workmanship.

Yellow Pine.—An expensive, but soft and easily worked wood. Yellow pine is the ideal wood for the amateur; it is easily worked, cuts without cracking, and does not dull the tools. It retains its shape splendidly; indeed, yellow pine, properly handled, will not warp; hence it is a favourite wood for important work. It has the property of transmitting and responding to sound vibrations in a remarkable degree, hence it is always used in the making of acoustic instruments—organ pipes of yellow pine have a soft, mellow "voice," which is highly suggestive of the properties of the wood. Piano sound-boards, monochord bases, tuning-fork boxes, etc., should all be made of yellow pine.

Yellow pine hardens on exposure to the air; consequently, though soft and easy to work, it soon becomes sufficiently hard to withstand the handling usually meted out to laboratory furniture. It is, however, useless in damp situations, and should in all cases be joined with glue rather than nails.

Mahogany.—This wood is a favourite for the making of instrument cases, bases, and back-boards, owing to its hardness, and the ease, therefore, with which it takes a good polish. The wood is light red in colour, with highly characteristic markings, but it is usually stained with some oxidizing liquid (bichromate of potash generally) before polishing, in order to deepen its colour. "Bismarck Brown" is also sometimes used for this purpose.

The wood is very apt to split in working, owing to the fact that the main strength of the wood is in the longitudinal fibres; the connecting cells having thin walls, dry down on seasoning, and form bridges much weaker than the rest of the timber; hence, in working wood such as mahogany, for example, one has to take every possible precaution against the splitting of the wood.

There is practically no reason for the preference of this wood over bass wood, save for its appearance.

Beech.—Beech is a hard wood, used for making scales, squares, wood and metal working tools, etc., in consequence of its power of retaining its shape, and the general compactness of its fibres. It is a heavy, close-grained wood, singularly free from common blemishes, and fairly easy to work, provided excellent tools are used and they are in excellent condition. In working, beech does not display unexpected irregularities, as is frequently the case with mahogany and bass wood. Beech wood does not "chip" readily, the transverse binding cells being strong; consequently little fear of its splitting while being worked need be felt. It is specially suitable for any portion of an instrument subject to vibration, or even to heavy blows.

Teak.—This wood is a heavy hard wood, of a dark colour, and of close grain. It has a peculiar odour due to the presence of a volatile oil. This oil renders the wood almost impervious to water, hence it is much used for making instruments and fittings likely to come in contact with water:—burette stands, filter stands, table tops, etc. The oil in teak also renders it a good insulator, so that switch bases, electrical distributing boards, and other simple electrical appliances are frequently made of this material.

It is not very easy to work, particularly if the wood be not free from knots, and the oil it contains is very offensive to the workman who has to deal with large quantities of the timber. Teak requires to be worked with very sharp tools, and these need frequent attention. The permanence of any article constructed of teak, however, recoups one for the extra trouble expended in the making, and the appearance of the wood is in its favour.

Teak should not, as a rule, be polished; an occasional rub with a cloth soaked in raw linseed oil is all that is necessary to keep it in excellent condition and appearance.

Ebony.—This is the heaviest of the common woods used in instrument making, the density being greater than that of water. It is used largely on account of its appearance, the black colour and the compactness of the wood making it almost indistinguishable from vulcanite. It is, of course, much more easily worked than vulcanite, hence not infrequently it

replaces that material. Ebony is not liable to split; it is a hard and compact material, and takes a good polish when necessary, though it is usually brought up to a fine finish and left so without polishing, a coat of raw linseed oil well rubbed in, and off, being all that is necessary to produce an excellent appearance. It is almost impervious to water, and is not likely to break down in laboratory work if used as an insulator. It is expensive, and used mainly in small and delicate work.

Box.—Boxwood is used chiefly in consequence of its power of retaining any shape it may be given. It may best be described, perhaps, as "like beech, only more so." It is of compact grain, and takes a high polish, which ensures it against atmospheric action. Solids for use in mensuration, scales, pulleys, and other appliances requiring absolute accuracy, in shape, alignment, etc., are made from this wood. It is not, however, an easy wood to work, being very easily split; consequently it is not in great request among amateur instrument makers.

Sycamore and **Holly** are hard, white, and somewhat brittle woods.

Black Walnut is used for instrument bases and frames.

Satin Walnut is sometimes used instead of bass wood for stands.

Oak is used for instrument bases and frames, and similar purposes, being strong and hard, though of somewhat open grain, brittle, and liable to split in working. Oak looks well when polished or "fumed," but iron nails and screws must not be used with it, as they are acted upon by the tannic acid in the wood, and gradually work loose.

The above four woods are not used to any very great extent because of their intrinsic properties. They are used occasionally in consequence of "figure," or because of their rich appearance when polished. Oak, however, has one remarkable and valuable property, viz.—that when heated in presence of moisture, it may be twisted into any shape, which will be retained on drying and cooling. In consequence of this property oak "springs" are frequently used in the construction of mechanical apparatus.

II. Tools.

A laboratory should be furnished with a set of tools, comprising the commoner woodworking tools; but it is not necessary, as a rule, to supply a complete carpenter's set. Most school laboratories, nowadays, are in proximity to a manual training shop, where woodwork is carried on, and special tools may be obtained thence; or work involving the use of special tools sent to the manual shop for execution, as it is just the special tools that demand special care and experience in handling.

A set of the tools in common use should, however, be supplied for the laboratory alone. Nothing is more annoying to the manual training teacher, and more conducive to slackness in his care of the tools, than to find that the "science man" has borrowed a plane or a chisel, and has returned the tool in a condition necessitating grinding—a not infrequent occurrence. Let the "science man" keep a set himself, and if he is unable to keep them in order, let him place himself under an obligation to the manual training instructor in this particular—it will be good for both.

The following is a list of tools recommended:—

One hammer.
One mallet.
One 10″ tenon saw.
One jack plane.
One smoothing plane.
One ¼″, ½″, ¾″, 1″ firmer chisels.
One ¼″ mortising chisel.
One ½″ gouge.
One half-round bastard file.
One gimlet.
One bradawl.
One screwdriver.
One spokeshave.
One trysquare.
One oilstone.
One gluepot and brush.
One marking gauge.
One bevel.
One brace and set of bits.
One expansion bit.
One pincers.
One set twist drills.

Care of Tools.—Tools for laboratory use are much more liable to rust than those kept in the woodwork shop, and consequently need extra precaution to be taken against this.

If possible, they should be kept in a box, with a special place for each tool, and the box should be fitted with lock and

key to prevent misuse. A rag which has been soaked in a mixture of two parts vaseline and one part paraffin wax should be kept in a tin box in this case, and iron and steel tools occasionally rubbed with this.

The wood parts of planes should be rubbed, when new, in similar manner with raw linseed oil (on no account may boiled oil be used). This fills the pores on the surface, keeps out the moisture, and helps to harden the planes so that they last longer, and also take marks less easily.

Sharpening.—The sharpening of tools is an art in itself, and one cannot do better than remark that "practice makes perfect," though the practice of this precept is (usually) detrimental to the tools. However, one must learn, and tools are nowadays constructed in such a way that allowance is made for this "learning."

"Sharpening" may be divided into two operations:—

(1) *Grinding.*—This is necessary when the cutting edge of a tool ceases to be a straight line (or an even curve). When a small piece is chipped out of a plane iron or chisel, the gap always leaves its mark upon the work, and the defect should be remedied at once. This can only be done by "grinding back"—a tedious operation, usually postponed as long as possible, with the result that there is a tendency to alter the cutting angle in order to secure a sharp edge. If, however, the cutting angle is to be correctly retained, a large amount of metal has to be removed by the oilstone—a waste of time and energy, and a source of detriment to the stone.

A grindstone should have a width ("face") of not less than 3″, should be about 24″ in diameter, and of fairly fine texture. Gritty stones cut more quickly, but remove the metal in larger pieces, consequently the subsequent sharpening takes longer. Grindstones should never be used dry, as this takes the "temper" out of the steel, yet must never be allowed to stand in water, as this softens the stone. This softening would not matter very much if distributed evenly throughout the stone, but as the stone usually settles to one place on the frame, by virtue of its centre of gravity, it softens most in one place. This tends to make the stone of an oblate or eccentric shape,

and this is annoying in grinding fine work. Hence some arrangement for emptying the trough under the stone should be made, and in addition a means of dropping water on the stone during grinding is necessary.

Plane irons are not infrequently made of a plate of fine steel welded upon a plate of softer and cheaper iron, consequently it is well to turn the stone *towards* the grinder, as this process tends to embed the steel particles in the following iron, and at the same time grinds the steel free from a serious amount of "wire edge."

The angle of grinding should be about 25°.

When the fault has quite disappeared, and the edge is straight and "square" with the sides, the tool may be dried and sharpened.

(2) *Sharpening.*—The ground tool is still unsharpened, despite the common fallacy that sharpening is performed upon a grindstone, and must have an "edge" put upon it. This is done by the use of an oilstone.

The choice of an oilstone is a matter of some difficulty. Washita stone is excellent and cheap (comparatively), but slow, while Arkansas stone is rapid, but expensive. Turkey stone is of an intermediate quality, and gives splendid edges to tools; but it cuts slowly. An Arkansas stone is worth its cost in time saved, but as it cuts quickly it must be used carefully, or extra work will result. Olive oil is spread upon the stone before use, and this, with the black particles of removed steel, should be wiped off before putting the stone away. It should be kept in a wooden case, with lid, as being a porous stone it is liable to suffer if exposed to moisture and dust. A good size is 8″ × 2″ × 1″.

In using a stone, it should be remembered that while the stone wears away the steel, the steel is performing a similar operation upon the stone, hence the necessity to use the whole surface equally. A plane iron should be held at an angle of about 35° to the stone, and rubbed forwards gently and firmly, pressing evenly with the finger tips on the front of the iron. The forward is the cutting stroke, and the iron may be brought backwards lightly and rapidly. The sharpening of a plane iron

wider than the stone is done by rubbing opposite ends of the edge upon the stone on alternate strokes, thus using the whole surface of the stone, and sharpening the whole edge. In the case of a jack plane iron, the edge should have the corners rounded off a little, in order to prevent its leaving marks on the wood, but smoothing plane irons and chisels are sharpened to a "square" edge. The stone having done its work, examination of the edge will disclose a small piece of metal still loosely adhering to the tool, and this, known as the "wire edge," is removed by stropping, either on the palm of the hand or upon a leather strip; the latter is preferable for beginners, but the former gives better and quicker results.

Setting of Tools.—Planes are set by placing the cap iron upon the plane iron, and bringing the two edges close together, the distance separating the two edges depending upon the work to be done. Jack planes usually have the cap iron set back from the cutting edge of the plane iron from $\frac{1}{16}''$ to $\frac{1}{8}''$. Trying planes may have their irons set finer, not exceeding $\frac{1}{16}''$; and smoothing planes have their irons set very close together, usually not exceeding $\frac{1}{32}''$ back. These figures are for fully screwed up irons; naturally they will be exceeded when the screwing is commenced.

Having fixed the cap iron, the double iron is placed in the plane mouth, and the wedge inserted, holding the plane in the left hand in such a way that the thumb prevents the wedge advancing too far. The iron is then advanced until up to $\frac{1}{16}''$ for a jack plane, and a mere glimmer for a smoothing plane is visible above the base. The wedge is then tightened by a single smart blow of the hammer. If this has advanced the iron too much, it may be withdrawn after a smart blow has been administered either to the top front or the back end of the plane.

The tool may then be tried upon the wood to be worked, and the iron readjusted if necessary.

The directions for sharpening plane irons may be considered to apply to most edged tools, save gouges, which are sharpened from either side by a chip of Arkansas stone.

Saws should only be sharpened by a tool maker.

III. Uses of Tools.

Planes.—In consequence of the smallness of the amount of material used in laboratory work, it will rarely be found necessary to use a trying plane, consequently one was not included in the list of tools recommended.

Jack Plane.—This tool is used for removing the rough outer surface from wood to be worked. When used only for such purpose, it is set very coarsely, $\frac{1}{16}''$ of the plane iron protruding from the mouth; but if, as in laboratory work, it is likely to be used instead of a trying plane, it should be set more finely, and less of the corners rounded off. The iron should protrude sufficiently far to allow of a shaving the full length of the material being cut without undue effort. If a full length shaving requires too much effort, the plane should be set more finely. To prevent the tool rising from the work, it is necessary to hold down the front of the plane firmly to the work in addition to pushing the tool along. Much depends upon the set of the plane irons, and experience is the best teacher upon this point.

In planing wood, it should be remembered that the fibres generally run at an angle with the surface, and that the plane will therefore tear up instead of cutting the wood if we plane against the grain. Should this occur, the wood should be turned round, so that the plane cuts in the direction in which the fibres approach the surface (Fig. 1). It will also be seen that in turning over the wood to plane the under surface, the wood should be turned endways, not sideways, over, which will place the fibres in the correct position again. Any tearing of the surface is usually due to planing in a wrong direction, provided properly sharpened tools are used, and is in consequence easily cured.

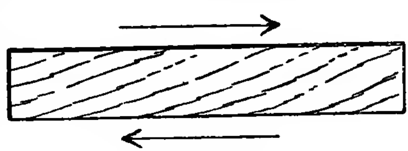


Fig. 1.

In planing end grain, the cut should be taken but half way

across, the wood then being reversed, and the rest planed. Otherwise, the wood will crack down as the plane reaches the end portion of the stroke (Fig. 2). A simple method of overcoming this difficulty is by the use of a "shooting-board," which provides a stop against which the wood rests, and thus receives the support necessary to prevent splitting.

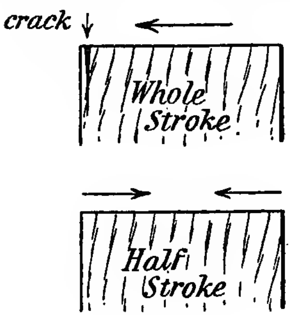


FIG. 2.

The rough surface being removed with a jack plane, a trying plane (or the jack plane set more finely) is used to make that surface fairly flat. A smoothing plane then takes out the plane marks previously made. It must therefore be very finely set.

The surface so produced may be still further finished by the use of glass paper.

Saws.—Many kinds of saw exist, but for the purposes of apparatus making only three need be mentioned: (*a*) the hand saw; (*b*) the tenon saw; (*c*) the bow saw.

(*a*) *The hand saw* is a long saw, usually constructed with teeth that permit cutting either with or across the grain. It is used when dealing with large pieces of timber, but should not be used when sawing thin, broad pieces, being a heavy tool, and liable to split the wood when this is disproportionately light. If it be desired to cut up strips of wood along the grain, a special saw (the rip saw) is used, but this is a still heavier tool, with coarsely set teeth, and requires practice in handling.

(*b*) *The tenon saw* is the most useful tool from our point of view. This saw is made of hard steel, and is kept rigid by a back plate, either of steel or brass. The teeth are small, and cut best across the grain, but are able to cut in any direction.

(*c*) *The bow saw* is used for cutting along curved lines. The saw blade is very narrow, and is kept rigid by the tension

on a twisted string, communicated to the saw blade by a wooden lever frame.

All our saws cut in one direction only—away from the operator; consequently, in sawing, the power should be given on the forward stroke, and care should be taken to keep the direction of the saw constant. It is well to remember that the arm and elbow should be in the plane of the cut to be made in order to secure a straight cut. It should be remembered also that the track of a saw cut is usually twice the width of the saw thickness.

Hammers.—Several kinds of hammer are in common use, either of those shown in Fig. 3 being recommended (see

a FIG. 3. *b*

also metalwork tools). Little need be said upon this, beyond pointing out that if one can use heavy tools comfortably they will do more work, provided they are used correctly. It is a common source of annoyance to be obliged to do a heavy job with a light tool. The hammer head is meant to be controlled by the handle, not to be pushed at its work by the handle, consequently it should be held well away from the head, and allowed to do its work by the momentum it acquires in the swing towards the work.

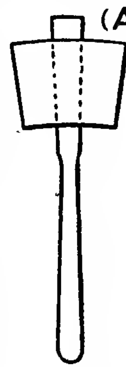


FIG. 4.

The same remark applies to the mallet, used for striking tools or pieces of work which the hammer would injure. The best shape is that sketched, as the angle of the handle end (A) (Fig. 4) prevents the head becoming loose or displaced. Mallet heads fastened on by a wedge of wood should be refused. The faces of the mallet

should be parts of radii of a circle having the elbow of the operator for a centre, in order to secure good square blows.

Chisels.—Chisels are of several kinds, "firmer chisels," "mortising chisels," etc. The former are used for all ordinary work, though sometimes they have the front edges ground away in order to permit of their use in a corner. A mallet should always be used when heavy striking of a chisel is necessary. Light striking is frequently performed by the hand, as also is paring. Work requiring a chisel should be arranged so that the tool may cut downwards, and if a bench is being used, a spare block of wood may be interposed, in order to save the bench from damage. Mortising chisels are made with heavy blades, and handles specially designed to permit the striking of heavy blows, as the chisel has to cut through thick and heavy wood.

Gouges are best described as curved chisels, and the remarks previously made will apply equally well.

Bradawl ("sprig bit").—This tool is used for piercing wood before the insertion of nails. It has a sharp cutting edge, which is inserted always *across* the fibres of the wood in order to cut these; otherwise it will act as a wedge, forcing the fibres apart, and doing exactly what its use is intended to prevent.

The uses of the rest of the tools are well known, and where any explanation is necessary, it will be given where the use is advocated.

The Bench.—It is important that some suitable bench be used for laboratory woodwork, if only to prevent the otherwise certain use of the laboratory tables. A bench should not be higher than 2′ 6″, and may be up to 2′ wide, and as long as is convenient, not less than 4′ 6″ or 5′. It should be made of stout 3″ × 3″ framing, and a top of 9″ × 1½″ or 9″ × 2″ boards of good hard wood, planed true.

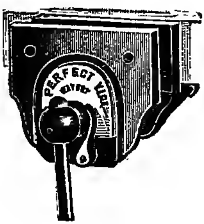


FIG. 5.

A planing stop of wood (not toothed metal) is recommended, and a "Parkinson" instantaneous

grip vice, see Fig. 5. Beyond these desiderata, the bench may take any convenient shape or form, that shown in Fig. 6 being

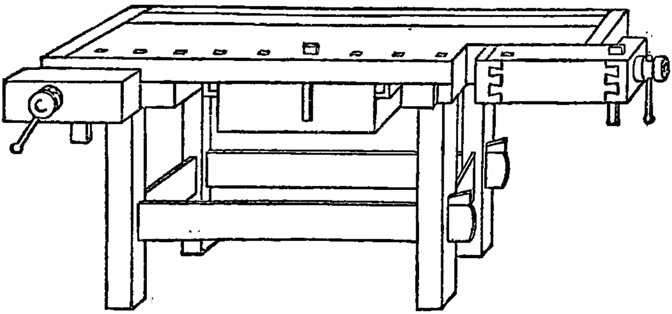


FIG. 6.—Carpenter's bench, with clamping device.

a useful type of bench for ordinary work though fitted with the common screws.

Glue.—Glue is an important aid to woodwork construction, and well repays a little care in its preparation. Various makes of glue are on the market, principally "Scotch," "French," or "Town," the first two of which are to be preferred.

As a rule, light-coloured glue is of the better quality.

The method of preparation recommended is as follows :—

Break up the glue into pieces not greater than half a square inch in area. Place these in a suitable vessel and cover well with water. Allow to stand overnight, then pour off any excess of water, and if all the glue has expanded, owing to absorbed water, it may be bodily removed to the inner glue pot, and heated for about an hour, when, after skimming, it is ready for use. Should only a portion of the glue have absorbed water the whole may still be melted up as before, but cold water should be added before heating, in quantity calculated to be sufficient to soften all the glue to an equal extent.

Glue is tested by its ability to run off the brush, which it should do in an unbroken stream. Glue, used in too concentrated a form, sets before it has had time to soak into the pores of the wood, and will subsequently chip off the

wood entirely; whereas glue used of proper consistency or strength will pull away pieces of the wood rather than break at the joint.

Glue deteriorates every time it is melted, consequently it is well to make frequently, and keep free from dust and shavings, etc., which, being gritty, prevent the wood surfaces coming into good contact.

Two pieces of wood to be jointed should first have their surfaces planed to a perfect contact. One piece should then be firmly gripped in the vice, surface upwards, and the other, inverted, *i.e.* surface upwards also, held alongside. The glue should then be quickly and evenly spread along the two surfaces, the second one quickly erected into position, and rubbed backwards and forwards several times along the fixed piece. Presently it will become difficult to move, when it should be finally brought to its desired position, and allowed to "dry" or "set." Cramping is usually unnecessary if the above method is adopted.

Nails and Screws.—Nails should rarely be used in apparatus making. Wood joints, well glued, will repay the time spent upon them, and where metal junctions are necessary screws should be used. In large and rough pieces of apparatus, however, nails are at times permissible, in which case oval steel "brads" should be used. These can be obtained in sizes from $\frac{1}{2}''$ to $3''$, and having the advantage of being oval, rarely split the wood. Moreover, they can be driven fully into the wood, and so become practically invisible.

Round "wire" nails (French nails) and "cut" nails should be avoided, being clumsy and not holding well in work adapted for laboratory use. Cabinet makers' "veneering pins" are sometimes useful, as also are "gimp tacks" for special purposes, but it may be taken that as a general rule the use of nails is to be deprecated. It is, in apparatus, the sign of slipshod work. A cabinet maker frequently makes the statement: "There is not a nail in it," as a proof of good work, and apparatus should at least be as well made. Sometimes he goes further, and says: "There is not a bit of metal in it," but there we cannot follow, as we are accustomed to take advantage of

the properties of metal from quite other motives than those of constructional rigidity.

Screws are occasionally necessary, and as a general rule brass screws are to be preferred to iron, and countersunk heads to round ones. These latter give a better appearance to work of composite character (metal and wood), but in screwing them "home" the heads are apt to snap off, all the bearing being taken at this point. It is easy to screw a round-headed screw too far, *i.e.* to give an extra turn after the screw is "home," in which case the head invariably cracks off, whereas a countersunk screw cannot be turned further when once "home."

IV. Woodwork Exercises.

The following exercises are selected as involving some typical woodwork, and not simply with the object of producing the article made. Students who are able to complete these exercises satisfactorily will find no difficulty in dealing with most of the woodwork required for the manufacture of Laboratory apparatus.

Note :—It is recommended that these exercises be worked in the stated order, as instructions given in respect of tools used for the first time are not repeated upon subsequent occasions.

Exercise 1.—*Whitewood stand for Hare's apparatus.*

Materials required:—Bass wood, $24'' \times 10'' \times \frac{1}{2}''$, $12'' \times 7'' \times 1''$ $9'' \times 3'' \times \frac{3}{4}''$; glue; two $1''$ No. 8 iron screws, one $1\frac{1}{4}''$ No. 7 iron screw.

Tools required:—Jack plane, smoothing plane, tenon saw, try-square, $\frac{1}{2}''$ mortise chisel, $1''$ and $\frac{1}{4}''$ firmer chisels, turnscrew, mallet, marking gauge.

Method:—Plane up all wood, until a smooth, even surface is reached, and no light appears under the trysquare blade when applied to the wood. This operation is more difficult than would appear at first sight, and is best attained by having the jack plane set so that only a thin shaving is removed at each stroke. Care must be taken to remove the wood from the heights only (which will explain the value of a plane longer than the ordinary jack plane), and the wood must be kept out of twist, and of equal thickness, determined by the use of a marking gauge.

When the wood is reduced to a level surface, mark the surface so produced, and plane one edge to an exact right angle with this surface. These are the standard "face and edge" from which all others are "squared" and marked.

Plane to thickness by scribing a mark round the whole piece with the marking gauge, set to the minimum thickness of the wood—the planed surface pressing against the stock of the gauge. Remove surplus wood indicated in this manner, and plane smooth with finely set smoothing plane.

By means of a trysquare squared to true "edge," mark the two ends of the wood at right angles to the true edge, and saw along these with the tenon saw. (*Note.* A bench hook (Fig. 7) is a great convenience here.) The saw should not be put *on* the line, but outside it, and the line should be drawn by a chisel, not a pencil; the cut will then present a clean edge instead of being frayed by the action of the saw.

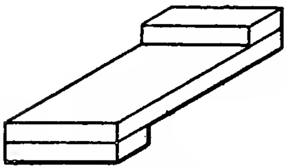


FIG. 7.—Bench hook.

The wood may now be marked out, in the shape shown in Fig. 8, leaving a tongue 4″ wide in the middle. The corners are

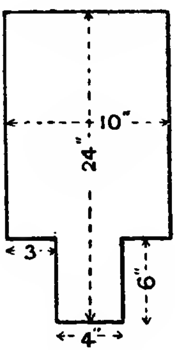


FIG. 8.

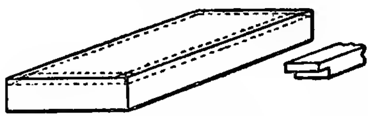


FIG. 9.—Base and thumb gauge for marking chamfer.

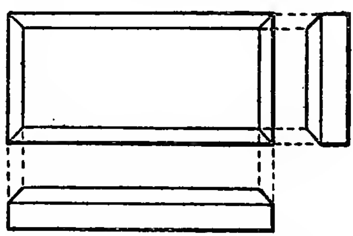


FIG. 10.—Base of stand chamfered.

now carefully sawn out (outside the lines), great care being used to keep the saw at right angles to the plane of the wood, when sawing

with the grain—any twisting of the saw blade once the saw-cut is started will result in the cracking of the wood.

Plane up the base similarly, and cut a "thumb gauge" (Fig. 9) from a piece of $1'' \times \frac{3}{4}''$ wood. Apply this to the upper face, and mark the depth all the way round the wood, and the amount overlapping the face.

By means of a jack plane remove the wood thus indicated, first along, then across the grain, and so form a chamfer round the upper face (Fig. 10).

Draw two parallel lines lengthwise across the top of the face, equidistant from the middle, and the width of the first piece apart. Mark out $1\frac{3}{4}''$ of this on each side the centre. Take the mortising chisel, place it in the space thus marked out, the flat face towards the outer edge of the marked-out rectangle, and about $\frac{1}{2}''$ away from extremity. Hold the chisel quite vertically, and give a sharp blow with the mallet. By a sloping cut remove the wedge-shaped piece so made, and then proceed to advance the chisel toward the end of the groove, always keeping the chisel upright, and the flat face facing the end of the groove. Do not attempt to go through the wood at first, but be content to cut out the groove to correct shape, and with square edges. Having reached one end of the groove, reverse wood or chisel, commence at the same point as before, and gradually cut to the second end of the groove, advancing about $\frac{1}{16}''$ at each cut. The cut-out wood may be removed by using the chisel as a lever. Having cleared the whole of the upper portion of this slot, recommence as before, and cut out the rest. It is important to cut the edges square to the face, otherwise the upright portion of the stand will not be vertical, or, if made vertical, will not be a tight fit in the groove or slot now cut.

Next, plane up the wood containing the back strut, and cut it diagonally right through (Fig. 11). One of the pieces is then to have the newly sawn edge planed up and the acute angle of the triangle removed (for appearance sake) by a chisel. To do this put the wood down on a cutting block (spare piece of wood), and holding the firmer chisel in the right hand vertically, guiding with the forefinger of the left, cut off the end by a sharp pressure on the chisel handle. Do not cut off too much at a time, or the fibres will offer so much resistance that they bend, and a clean cut will not result. Better take several cuts, a little further back each time, until the cut is about $\frac{3}{8}''$ wide.

The triangle so made will not fill up the place it is to fit, and it may now be further prepared by squaring to the hypotenuse in

such a place as to produce a triangle of maximum size (A). A line should be scribed on each side of the piece, and another should be scribed $\frac{1}{4}''$ from the face, all round the newly made triangle: Saw cuts inside the line along A, on both sides, and others outside the line to meet these down the grain, will cut away two cheeks and leave a tongue which projects into the base of the stand

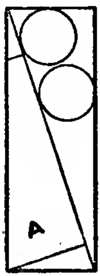
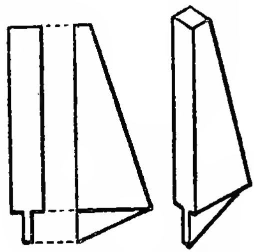


FIG. 11.



(*a*) (*b*)

FIG. 12.—(*a*) Elevations. (*b*) View of back strut.

already made. The saw cuts should be made by fixing the wood in the bench vice, and commencing to cut along one of the scribed lines, penetrating the surface as little as possible, until the line has been traversed, when the saw should be sloped, and the second line similarly cut; these cuts will then serve as guides to the saw in the subsequent cutting down to the line A, which may now be proceeded with, holding the saw parallel to A.

Place for this tongue is now scribed out on the base board of the stand, and two saw cuts made (sawing on the inside of the line) at right angles to the slot already cut, which will permit the access of the saw. After removing the surplus wood with a $\frac{1}{4}''$ firmer chisel, the triangular piece may be fitted to the groove just cut.

Before erecting, it will be well to cut the holes in the face, cutting half way from each side, one $\frac{3}{4}''$ diameter, and two $\frac{1}{4}''$ or $\frac{3}{8}''$ diameter in the positions indicated, the wood between these two latter holes being sawn out; also to cut $\frac{1}{4}''$ shoulders on the tongue of the upright piece, as shown in Fig. 13. Two saw cuts may also be made about $\frac{3}{8}''$ from the outer edge of the tongue, as indicated in Fig. 13, and about $1\frac{1}{4}''$ long. Two wedges, the thickness of the wood cut from the two corners, $2''$ long and $\frac{1}{4}''$ wide at the thick end, should also be cut, and a $\frac{1}{8}''$ hole drilled at right angles to the tongue of the back stay through the base, and countersunk to take the head of the larger screw.

Erecting may now be accomplished by dipping the tongue of the large piece in hot glue, hammering it well in up to the shoulder, dipping the wedges in glue, inserting these in the cuts already prepared for them, and hammering them in till tight. The back stay now has its tongue dipped in glue, is inserted in its place, and the screw is well driven home before the glue sets. It only remains to screw in the two smaller screws at C and D (countersunk holes should be prepared for them) and the stand is complete. Care should be taken to have all work done before erection is commenced, in order that this may be completed before the glue sets.

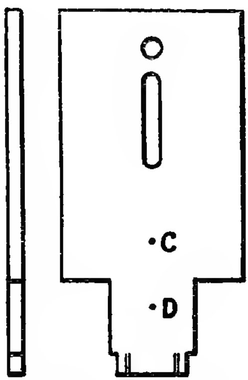


FIG. 13.—End and front elevation of upright portion.

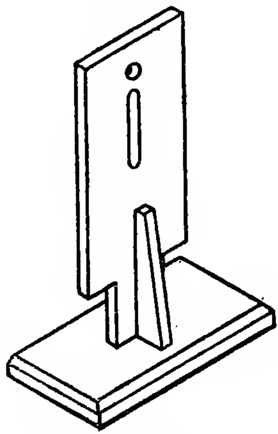


FIG. 14.—View of completed stand.

Holes for screws are drilled with a "spoon bit"; a gimlet is not recommended. The tops of these holes are countersunk for the screwhead by a special "bit"—of a different pattern for hard and soft woods.

When the glue has thoroughly set, which will take twenty-four hours, as a rule, during which time the apparatus should be kept in a warm place, the projecting ends of the wedges may be sawn off, and the bottom cleaned with a smoothing plane set rather coarsely, or a finely set jack plane.

Supports for beakers may readily be cut from the remaining piece of $\frac{3}{4}''$ wood, by means of a bow saw, the shape recommended being that shown in Fig. 15, and they may be fastened to the base,

as the blocks are not then liable to be lost. Attachment may be made either—

1. By cutting a "lug" on the block, and screwing through this lug (Fig. 15), or—

2. By a strip of brass, let into the base of the block and screwed into the base of the stand (Fig. 16). (*See* METALWORK for method of working brass.)

FIG. 15.

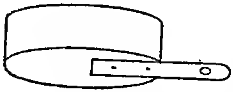


FIG. 16.

The stand may now be cleaned up with fine glass paper supported on a cork block, and stained mahogany colour (with "Bismarck brown" dissolved in methylated spirit), or walnut colour (with "Vandyke brown" dissolved in ammonia solution), after which it may be sized with weak glue, and varnished with dark oak (inside) varnish. Or it may simply be coated with a black material—lampblack, shellac, and methylated spirit—when it is ready for the mounting of the tubes. Details of the composition of these stains will be found in Section IV.

EXERCISE 2.—*Teak and vulcanite base for plug key.*

The making of this will cause little trouble, the only new point being in the handling of the new material.

Materials required:—Teak, $4'' \times 4'' \times \frac{3}{4}''$; vulcanite, $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{4}''$; four brass countersunk screws, $\frac{1}{2}''$ No. 6.

Tools required:—Plane, square, turnscrew, brace, and countersinking bit, twist drill to take screws, gimlet or bradawl, emery-paper, glass-paper.

Method:—Plane up the teak to size, and mark a chamfer $\frac{1}{4}''$ off each edge. Plane this off, and glass paper the whole to a good finish.

The vulcanite plate may not be exactly to size. It may be sawn in shape by a tenon saw, and rubbed down to exact size by rubbing an edge on coarse emery paper. The edges should be slightly rounded, see Fig. 17, and the plate should be finished to fit the top of the wooden base exactly.

Holes are drilled in the vulcanite by means of a twist drill—not spoon-bit, or gimlet—as these bore too quickly and would split the material. The screw holes are placed at the four corners, $\frac{3}{8}''$ from each edge. Countersinking may be performed either by the hard-wood countersinking bit, or by a twist drill about three times the diameter of that required for the screw hole.

When the holes are drilled and countersunk, the drill may be put down each hole in turn while the vulcanite is being held in place on the wooden base, thus marking the positions of the holding screws. The base is then removed, and a bradawl or gimlet is used to make a hole in the wood big enough to ensure the screw taking up its right position. This will be the case if the hole is $\frac{1}{4}''$ deep, and exactly vertical. Replace the vulcanite plate, and insert the screws, taking care to push them well home, and level with the top of the plate, but not so far as to strain the vulcanite unduly.

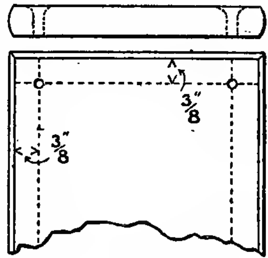


FIG. 17.

Note that the gimlet is not to be put through the vulcanite plate to reach the wood—this would probably result in cracking off the corner of the vulcanite plate—and that the holding-down screws, while tight, yet must not produce a compression strain on the vulcanite, and must be level with the top of the plate.

The above exercise looks very easy, but care will be required to complete it correctly, as no glass-paper must be used on the face of the vulcanite, which indeed scratches very easily, and is thus ruined in appearance. The exercise is one involving delicate handling as well as accurate work.

EXERCISE 3.—*Lantern cell in mahogany, or cedar.*

Materials required:—An empty cigar box (100 size); mahogany strip, $10'' \times 2'' \times \frac{1}{2}''$; brass escutcheon pins or veneering pins;[1] two glass plates,[2] $4'' \times 3\frac{1}{2}''$; one foot $\frac{3}{8}''$ I.R. tubing.

Tools required:—Plane, chisel, hammer, trysquare, glue.

Method:—Take the cigar box to pieces carefully and select the best sides to give two pieces $8'' \times 4''$. Draw a circle $3''$ diameter centreing at the intersection of the diagonals of the two $8'' \times 4''$

[1] Failing these, use nails from the cigar box itself.

[2] These $4'' \times 3\frac{1}{2}''$ glass plates should be of "patent plate" glass with optically true surfaces. Such glass is about $\frac{3}{32}''$ thick. Failing this, ordinary "$\frac{1}{4}$-plate" stripped photographic plates will do, but the cell will suffer in consequence, there not being quite enough overlap of wood to render it thoroughly water-tight, unless the dimensions are suitably altered, and a smaller "field" used.

pieces, and cut out this circle[1] by means of a gouge, which should be well sharpened, and sloped towards the centre, while cutting. The blows given to the gouge should not be too heavy or, when with the grain, the wood will probably split. There is not so much likelihood of this in cutting against the grain. Having completed a rough circle about $\frac{1}{8}''$ inside the mark, gradually extend this out-

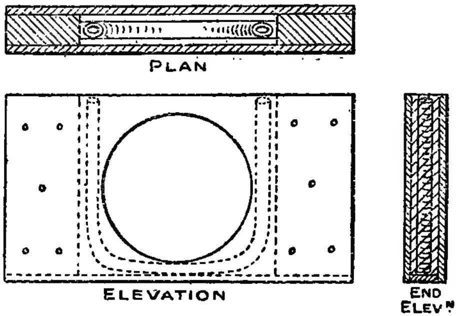


FIG. 18.—Plan and elevations of lantern cell.

wards, holding the gouge vertically, until the circle is completely and cleanly cut. Finish with the curved side of a half-round file. Treat the second piece similarly.

Plane up the $10'' \times 2'' \times \frac{1}{2}''$ strip and take $\frac{1}{16}''$ off the width,

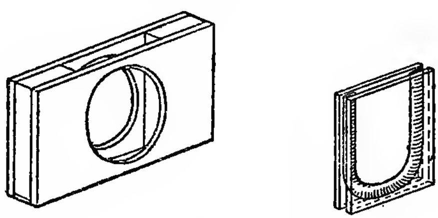


FIG. 19.—View of cell and plates.

making it $10'' \times 1\frac{15}{16}'' \times \frac{1}{2}''$ finished.

Cut off from this two pieces, each $3\frac{7}{8}''$ long; glue both sides of each of these strips; place one of the thin pieces of wood on a firm support, and fix the strips in place, each having two of its edges

[1] A special cutting tool is known to carpenters for this purpose, but an ordinary "washer cutter" will do admirably.

coinciding with the upper and outer edges of the thin piece on each side of the circle. Place the other thin piece on top in its place, and secure the whole by five veneering pins on each side, and on each face (twenty in all) in the positions shown.

When this is finished, a strip $8'' \times \frac{1}{2}'' \times \frac{1}{8}''$ from the cigar box material is glued into the slot left along the base, and similarly secured. The whole is allowed to stand in a warm place for twenty-four hours, and then well glass-papered, stained, and varnished, or French-polished—the latter is to be preferred.

To complete the cell it is only necessary to squeeze the I.R. tubing between the two glass plates in the manner indicated in the diagram, and to slip these plates into the frame already prepared. On releasing the pressure, the I.R. tubing will expand, and press the plates tightly against the framework, making a perfectly water-tight cell, which has the great advantage of being easily cleaned on the inside.

EXERCISE 4.—*A teak box to hold* 50 *lantern slides.*

Materials required:—Teak, $11'' \times 7'' \times \frac{1}{2}''$, $8'' \times 9'' \times \frac{3}{8}''$; 1 pair brass butt hinges, $1'' \times \frac{1}{4}''$, and screws; 1 hook (brass); 1 countersunk and 1 roundhead screw for above, veneering pins or $\frac{1}{2}''$ oval brads; 6 brass $\frac{5}{8}''$ screws (countersunk heads).

Tools required:—Hammer, tenon saw, marking gauge, bevel, trysquare, plane, glass-paper.

Method:—Saw the larger piece of teak down the middle, and plane each piece to $11'' \times 3\frac{3}{8}'' \times \frac{3}{8}''$. Saw the second piece after planing to give one piece $8'' \times 4\frac{5}{8}'' \times \frac{1}{4}''$, and the other $8'' \times 4\frac{1}{8}'' \times \frac{1}{4}''$ when finished.

The following pieces can now be obtained—

two $4\frac{1}{8}'' \times 3\frac{3}{8}'' \times \frac{3}{8}''$ (ends),
two $6\frac{1}{2}'' \times 3\frac{3}{8}'' \times \frac{3}{8}''$ (sides),
one $7'' \times 4\frac{5}{8}'' \times \frac{1}{4}''$ (bottom),
one $6\frac{1}{2}'' \times 4\frac{1}{8}'' \times \frac{1}{4}''$ (top).

Scribe the two ends and sides of each piece $\frac{3}{8}''$ from the ends and parallel to them, by means of the marking gauge, and on the two $6\frac{1}{2}''$ pieces scribe the three dovetails as shown in Fig. 20, which gives a wide dovetail at the top. The shaded portions are then removed, by sawing inside the line down to the scribing line, and then removing the surplus wood with a chisel, taking care not to start too near the scribing line. Proceed similarly at each end of the two $6\frac{1}{2}''$ pieces. Then place one of the two

$4\frac{1}{8}''$ pieces in the bench vice, hold one of the $6\frac{1}{2}''$ pieces above it in the position it has eventually to occupy, and mark by means of a chisel or other sharp instrument the positions of the dovetails. With the trysquare carry these down on each side to the scribing line, and finally saw down the lines marked, *on the outsides*, leaving the dovetail large enough to fit accurately into the place already cut for it. Remove the surplus wood as before, taking great care of the dovetail this time. Treat all the corners similarly.

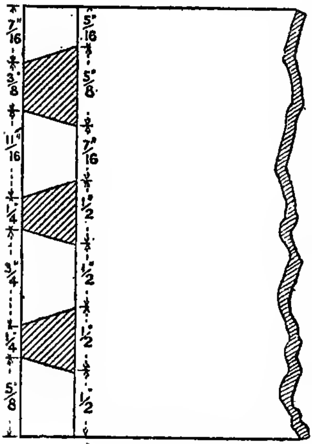


FIG. 20.

When these are finished the dovetails may be dipped in glue and fitted, the two ends to one side first, and lastly the fourth side. They should not require much hammering to bring them home, gentle tapping being all that is necessary in a well-cut joint.

After glueing, the whole may be tied tightly round with string, and the top and bottom fixed. These should already have been planed up true, and cut roughly to size. It is best to leave the top about $\frac{1}{16}''$ "full" (*i.e.* $\frac{1}{8}''$ longer and wider than the actual top), while the bottom should be planed up until it is exactly $\frac{1}{2}''$ longer and wider than the box, and the upper edges rounded. The box being now placed upon the base, the inside and outside are marked upon the base, and six screw holes drilled in the positions shown in Fig. 21, countersunk at the bottom. Top and bottom edges of the box are now well glued, fixed in position, and the six bottom screws put in. The top holds quite well with glue only, but, if thought advisable, six small $\frac{1}{2}''$ brads may be used on the top in similar positions to those of the screws in the base. When quite "dry," the box should be cleaned up, a chisel removing surplus glue, and the top planed down level with the sides. The upper surface may be rounded to match the base if no brads have been used in affixing it, otherwise it must be left square.

After cleaning and glass-papering, mark round the box in the middle of the largest dovetail, and with a fine tenon saw cut round this line. The lid will now be separate from the box, and

will only need its edges planing, this work being small if the saw cut has been carefully made.

The hinges may now be fixed by chiselling a small recess in the edge of the box, to the depth of half the hinge, and fixing the hinge with a projection sufficient to bring the pin holding the hinge together in a straight line with the edge of the box. Fix both hinges on the box first, then mark their position on the lid, cut out the place for them and fix to the lid.

The hook is easily fixed on the front.

A box such as that described, of teak, should not be varnished

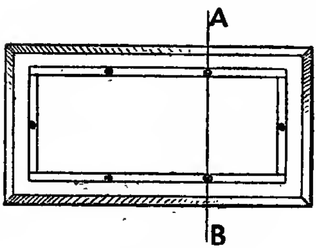


FIG. 21.

FIG. 22.—Part section across A B showing countersunk screw holes.

or polished, but rubbed with a little linseed oil, or even left "white."[1] The box will be found to hold fifty slides conveniently; boxes with grooves are not used much nowadays, though frequently partitions are placed at suitable positions down the box. This could have been arranged in this case by taking two saw cuts, $\frac{1}{8}''$ deep and $\frac{1}{8}''$ apart, opposite each other on the insides of the sides before putting together, the wood between the saw cuts being removed. A strip of cigar box fitted into this groove serves as an excellent partition.

V. THE "FINISHING" OF WOODWORK.

Woodwork fresh from the plane is not in a suitable condition for varnishing or polishing. The plane marks are removed by successively finer grades of glass-paper, wrapped round a squared block of cork, and rubbed with the grain in much the same way as a saw would be used, *i.e.* firmly forwards and lightly backwards.

When the surface is quite smooth, it may be stained and varnished, or polished, as desired.

[1] Untouched after glass-papering.

As a rule, water stains are superior to spirit stains, producing a more evenly coloured surface with greater ease, and not being liable to show streaks of heavier colour.

The simplest preservative of woodwork is shellac varnish. This is made by soaking flake shellac in methylated spirit twenty-four hours, then stirring and shaking frequently and vigorously until a homogeneous liquid is produced. To this about 5 per cent. raw linseed oil is added, and the varnish is ready for use. The glass-papered surface is rubbed with raw linseed oil on a piece of cheese cloth, and allowed to stand for a few minutes. The varnish is then applied with a wide camel-hair brush, and it should not be stinted in quantity, as whatever does not soak in, may be used up by brushing it to a new portion. A few minutes will serve to dry it completely, and any depth of colour may be obtained by repeating the varnishing.

Hard woods are not treated with coarse glass-paper, the labour being too great, and the scratches produced being difficult to remove. The surface is first scraped by pushing over it a $3'' \times 2''$ piece of saw steel, with absolutely square edges—this being inclined slightly to the wood, and bent across the thumbs (Fig. 23). Light shavings or parings are thus removed, and these may be taken from any projecting fibre, reducing it at once to the plane of the surface.

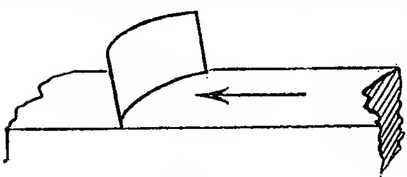


FIG. 23.

Having removed all plane marks, fine glass-paper is used as before, and the surface brought to any desired state of fineness. In hard woods, which are frequently porous, the dust from the glass-paper helps to fill up the pores, and so produce a better surface, but in no case are hard woods suitably treated with shellac varnish. They should either be oiled or French polished.

Teak and oak may be oiled or wax-polished with advantage. Raw linseed oil containing 5 per cent. of white wax melted in and allowed to cool, is applied on cheese cloth as before, and, when this has soaked in, the surface is well polished with a linen cloth. The surface so produced is a very pleasing one, and has the advantage that dust does not collect upon it readily, and that it does not become dull, though, of course, it never will be very bright. Oak to be so polished should be previously rubbed with a dilute solution

of bichromate of potash in water, applied with cheese cloth, each part of the surface being treated once only.

Walnut and mahogany may be treated as above, but after staining and oiling should be French polished (see Section IV.); and, indeed, oak is for many purposes improved by a thin layer of French polish. French polish, or a fairly heavy wax polish, preserves the wood from water, acids, and alkalies better than any other preparation, and though it is a little more trouble, the enhanced effect will adequately repay the extra labour expended upon the work.

NOTE.—Wood screws, of iron or brass, are numbered according to the following rule :—

No. 4 has a diameter of $\frac{1}{8}''$, each succeeding number adding $\frac{1}{64}''$ to the diameter of the screw. This applies to all lengths.

The length of countersunk screws is measured "over all," that of round-headed screws, from under the head.

SECTION II

METAL WORKING

I. Metals.

THE materials we have to make use of are chiefly: iron and steel, brass, tin plate ("tin"), copper, and to a less extent, aluminium, platinum, zinc, and silver.

As with wood, metals are used for their intrinsic properties, not on account of cost; rather, indeed, as in the case of platinum, in spite of cost.

The properties of these metals are generally better known than those of woods.

Cast Iron.—This is a hard, brittle metal, of many grades and qualities. The best "close grained" cast iron only is used in making apparatus, and our experience of the metal will be largely connected with repairs. Cast iron files easily and cleanly, and drills well, but care must be taken when dealing with thin pieces, owing to the brittleness of the metal. Similarly when "tapping" a screw thread it should be remembered that from the same reason, threads in cast iron easily "strip."

Iron, especially in its purer form steel, being very sensitive to the time-factor in cooling, is a somewhat troublesome metal to deal with by means of heat, but as the manner and methods of control become better known, it is soon found that this property gives a much wider range of usefulness to the metal than is possessed by any other.

Cast iron, cooling first and most rapidly from the outside, usually presents a very hard "skin" which is very difficult to penetrate, even by a file, but once this is removed, the

metal works easily. A well-made "fine" casting in iron is as pleasant to work as any brass or gun-metal casting, and with care can be made to look as handsome. Being tougher than these metals, however, the labour expended in working it is somewhat greater.

Wrought Iron.—This, the purest kind of iron chemically, is most easily worked hot, when it may be hammered into any desired shape. It is a useful exercise to heat "cut" nails in a foot-blowpipe, and hammer these on a bench anvil into staples, hooks, "riders" for levers, and other useful articles. Wrought iron is usefully stocked in strips, $\frac{1}{4}''$, $\frac{1}{2}''$, and $1''$ wide, and of various gauges, from No. 18, $\frac{1}{20}''$, to No. 11, $\frac{1}{8}''$. Six feet of each kind will stock a laboratory for a long time, and will prove extremely useful in a thousand ways in the repairing of apparatus; a simple example being to use such a strip for binding together two broken pieces of an article such as a galvanometer jacket, or even the mouth of a bell jar, two co-incident holes being drilled in an iron strip at the lap, and a suitable copper rivet inserted and riveted up, or a small bolt and nut being used.

Steel is of several kinds, with widely differing properties. Cast steel—tool steel—is perhaps the most useful, but mild Bessemer steel is not to be despised, holding, as it does, an intermediate place between cast steel and wrought iron.

Tool steel has the great advantage that its hardness may be altered to any desired degree. It may be softened to work, and then hardened, if necessary, so that a tool will no longer produce a scratch upon it. For this reason it is invaluable in many instruments, particularly in parts subject to wear by friction.[1]

Mild steel is less susceptible to "tempering," but not altogether immune. It is tougher, less brittle, and easier to work than cast steel, but it has not the tenacity, the hardness,

[1] To soften steel, it should be heated to a full red heat, kept so a few moments, and allowed to cool slowly, either in the air, or in a bucket of sand. To restore the hardness, heat to the same temperature, and plunge into a bucket of water, or if great hardness is required, plunge into a vessel containing olive oil. See also page 62.

and the resistance to wear offered by the other material. It is used in constructional work, *e.g.* rods supporting weights, tie rods on apparatus, screw shafts. Callipers[1] and similar tools and appliances are often made of this material.

Both cast and mild steel may be obtained in almost any desired size, sheets $\frac{1}{16}''$ thick, of any area, or rods of any shape or size in section being listed by tool makers. An old saw blade answers many purposes admirably, and will serve as a stock from which this material may be drawn as occasion demands. Steel is cut with a hack saw, or a "cold steel chisel."

Many steels containing small quantities of nickel, tungsten, vanadium, chromium, etc., are now available for special purposes. These, however, are not of great service to the makers of laboratory apparatus of the type contemplated in this volume, though unquestionably of immense value in the manufacture of tools, of parts of machinery subject to excessive vibration and in similar special cases.

Brass, Gunmetal, Bronze, Phosphor Bronze.—These alloys all contain copper as the principal constituent, the secondary constituents endowing the alloy with various valuable properties.

Brass is a very variable material; it differs in composition, density, and colour, the quality being difficult to judge until working commences. As a rule it may be taken that "white" (light-coloured) brass is of inferior quality, though some grades of bright yellow metal, such as that of which paper fasteners are made, are extremely valuable because of their pliability. These, however, are special preparations. "White" brass is usually cast; it contains much zinc, and is more brittle, and more liable to contain "blow-holes" than the darker grades, which, containing more copper, are more expensive.

The price of brass is not altogether dependent upon the amount of copper present, though this is an important factor; but also upon the fact that extra copper means a higher melting point, and consequently more coal for the preparation of the alloy.

[1] Callipers should be made of "shear" steel, which is much harder than mild steel, though bought tools are frequently made as described.

Brass castings, rich in zinc (up to 30 per cent.), are of a light colour, and are liable to contain "blow-holes," caused by the vaporization of the zinc at the time of its addition, and too early a "pouring" of the alloy. In making brass, the zinc, being easily vaporized, is added to melted copper immediately before casting takes place, and if stirred or "poled" with a wooden rod, the product loses some of its hardness; yet some process of stirring should be adopted in order to secure even admixture and freedom from blow-holes.

Compromise is nowadays effected by reducing the proportion of zinc, and producing the softer "red brass" more like gunmetal, which, however, becomes too soft for the purposes to which brass is applied if the proportion of zinc is lower than 10 per cent.

Brass for making into sheet contains a higher proportion of zinc (15 per cent.), in order that subsequent rolling may not remove too much of the hardness to which the alloy owes its popularity. Sheet brass may be softened for working by making it nearly red hot, and quenching in cold water, the hardness being restored by re-heating and allowing to cool slowly in the air, or, if great hardness is required, in sand or sawdust. It will be noted that the opposite effects are produced upon steel by the above treatment.

Brass is largely used in instrument making, as it does not easily rust or corrode, yet is sufficiently hard and tough to stand ordinary strains, and sufficiently easy to work to ensure a reasonable price for the resulting product.

Rod brass is cut with a hack saw, and sheet brass with shears. Brass rod may be obtained in any size and shape of section, and sheet in varying thicknesses, from $\frac{1}{16}''$ to $\frac{1}{4}''$.

Brass turns red when rubbed with an acid, as the zinc is dissolved out, in preference to the copper.

Commercial "Tin" consists of a thin sheet of iron, coated on each side with tin. When the coating is thin, the iron soon shows through, and rusting commences.

The material is not in general use in laboratories, save for accessories of little importance.

It is cut with shears or snips, is very easily worked, being

soldered and riveted with the greatest ease. As, however, it soon rusts, very little time should be spent in making apparatus of this material.

Zinc is used for making water troughs and similar vessels. In a chemical laboratory it is an unsatisfactory metal, being attacked by acids, and by mercury. Its use as a lining for sinks, or in any other capacity connected with laboratory drainage, cannot be too highly deprecated.

Copper is a familiar metal in every laboratory. Its value lies principally in its high conductivity of heat and its resistance to the ordinary process of oxidation.

It is affected by the fumes of nitric and hydrochloric acids, and by ammonium salts, consequently it cannot be said to escape altogether the usual penalty of a laboratory atmosphere. The great ductility of copper permits it to be "spun" and moulded to a great number of shapes; seamless vessels now being available, making very valuable additions to laboratory equipment. Calorimeters of copper, brass, and aluminium, without a joint of any kind, may now be obtained from any dealer in physical apparatus, and the old soldered calorimeters are no longer justifiably used. Copper is used in the construction of air-, water-, and sand-baths, and much other laboratory apparatus. Its use in sand-baths is a mistake in the opinion of many teachers, the copper being liable to oxidize and scale in use, causing dirty sand and frequent trouble in other ways.

Copper rivets for the jointing of leather, and metal, are in general use, its malleability enabling one to make a good joint with the minimum of trouble.

Aluminium is used in "spun calorimeters," and sheets of aluminium are usefully cut up to make "clips" and "saddles" for fixing apparatus to stands, base- or back-boards. The metal does not easily corrode, bends with little trouble and does not crack in bending at right angles as much as brass does. Its appearance in this connection is in its favour.

Owing to its lightness and freedom from liability to corrode, aluminium would be much more freely used in the laboratory were it possible to work it easily. Practically the only satisfactory method of working aluminium is that known as spinning.

It is difficult to solder, though some success has attended the author's attempts to solder this material with a fluxless solder consisting of 92 per cent. tin and 8 per cent. zinc, using an aluminium bit "tinned" with the same solder, and having all surfaces cleaned by strong potash solution, rinsed in hot water, dried and heated before commencement.

Riveting is, of course, a satisfactory method of jointing, but the aluminium rivets have to be made by the worker.

Platinum is mainly of use to the apparatus maker when it is necessary to lead an electric current through glass. The fact that its coefficient of expansion is almost identical with that of glass renders this metal peculiarly serviceable in this respect, it being the only one that can safely be used for such a purpose. Were platinum cheaper, its intrinsic properties would make it the most useful and widely used of metals in chemical and physical laboratories, but its price is prohibitive. Would we could rediscover some of the cargoes of "Little Silver" thrown away by the Spaniards! Platinum is practically non-corrosive, is easily worked cold, bending with little danger of breakage, and being readily hammered into any desired shape. It welds easily, consequently jointing offers no trouble, and no foreign metal or solder need be used. This, in itself, is a property of immense value in the manufacture of physical apparatus.

Silver is a metal much used in the making of scales and mirrors. Its principal value in apparatus making arises from its softness in working, which makes engraving easy; its ductility, which ensures freedom from fracture; its brightness (partly due to the softness of the metal) and ease of burnishing, and a certain resistance to corrosion. Silver is, however, attacked by ammonium salts, particularly the chloride, by common salt, and by nitric acid, even when dilute. Though it tarnishes in a laboratory the atmosphere of which frequently contains sulphur compounds, the tarnish is easily removed by a chamois leather dusted with precipitated chalk or with rouge; and as apparatus having delicate silver scales is usually of a type kept in cases, this disadvantage is not serious. Silver is an easy metal to work, turning, drilling, and moulding by the hammer being carried out with ease, while the alternative

possibilities of burnishing to a brilliant reflecting surface, or of frosting to a beautiful grey finish, give a range for the exercise of individual taste not possessed by many metals. Its conductivity is the highest known, and its rate of expansion is accurately known, in common with most of its physical constants. Silver is used as a standard of comparison largely because of the purity in which it can be obtained, the high melting point, and the non-corroding nature of the metal.

Lead is a metal that should surely be more used in the making of apparatus. It corrodes very slowly, it is easily beaten into any desired shape, it may be cast in the roughest of moulds, and makes excellent joints between bolted surfaces. It is used for making heavy bases for instruments that would otherwise be "top heavy," for making small crucibles for use with hydrofluoric acid and for the entire drainage systems of physical and chemical laboratories; though, owing to the action of mercury upon it, it is now being replaced by enamelled earthenware for this purpose.

The ease with which it is beaten or hammered into any desired shape makes it of great service in a laboratory. Lead wire is a case in point. This wire is now frequently placed between two flanges of a joint, and when these flanges are bolted tightly together, the lead is squeezed into practically perfect contact with each flange, and a secure hydraulic joint results. Similarly in the adjustment of instruments put together with studs or nuts, a piece of lead wire is sometimes passed round outside the studs, so that in pulling up the two surfaces one nut may be tightened more than another, and the axes of the two portions brought exactly into line.

Lead wire is also useful for the manufacture of "riders" in lever experiments, numbers 16 to 20 being the most suitable.

II. Tools.

The tools for metalwork are of a different order from woodworking tools, since we have to deal with a much harder material. Metalwork is therefore more difficult than woodwork,

inasmuch as it requires greater labour to produce, but it is easier than woodwork in that the desired effect is produced more slowly, consequently an error is likely to be seen before it grows to incurable proportions. A plane, for instance, may remove at one stroke more than the excess of wood, but a file at one stroke would not be liable to remove too much metal. There is more tendency to commit one mistake while avoiding another in woodwork than in metalwork, hence the extra satisfaction to be gained by the more difficult work. There is, too, a permanence about metallic productions absent from those of wood.

The tools needed are mainly—

One hammer (heavy).
One riveting hammer.
One hack saw.
One soldering iron (1 lb.).
One pair cutting pliers.
One pair round-nosed pliers.
One small hand drill.
One jeweller's turn screw.
One steel straight-edge or try-square.
One tinman's snips.
One bench anvil.
One parallel jaw vice.
One cold steel chisel, $\frac{3}{4}''$ face.
One pair outside, one pair inside callipers.
One large flat file, 10″.
One half round bastard file, 10″.
One second cut safe-edge file, 8″.
One card small files (assorted).
Handles for above.
Set of stocks and dies and taps, $\frac{1}{2}''$ to $\frac{1}{16}''$.

Additional apparatus, if much work in tin-plate is contemplated, would be a special "bick iron" or bending plate.

Hammer.—This should be an engineer's "ball pane" of the kind illustrated on Plate II. The head should weigh about $1\frac{1}{2}$ lbs., and the shaft should be 12″ long.

Riveting Hammer.—This should be a light-headed tool with a handle about 12″ long, the head not exceeding 8 ozs. in weight. It is not necessary to procure this hammer if a straight pane tool has been obtained for woodwork.

Hack Saw.—An 8″ or 10″ bladed saw will be ample, but a stock of at least a dozen blades should be obtained. The coarse quality cuts more quickly than the fine, and is, on the whole, to be preferred for our work.

Soldering Iron.—Many kinds of soldering irons are to be obtained, and upon one's personal preference for any particular shape depends the quality of work turned out. The straight type of iron is inconvenient for many purposes, as it is often difficult to see what one is doing with it, and the hatchet type is therefore to be preferred. G. Adams and Co., of 144, High Holborn, list a tool at 2*s.* 3*d.* of 14 oz. bit (Fig. 24), which may be turned either way, and which is therefore convenient so far as this goes, but it is small, and thus there is a rapid loss of heat which causes much waste of time. The bit should not weigh less than 1 lb., and it may safely be taken that the heavier the bit, the better the work and more easily is it accomplished.

Should it be too heavy, however, it will tire the worker, and an unnecessary physical strain will result. Each worker should,

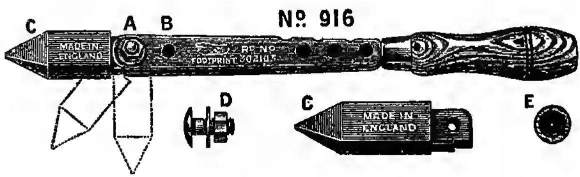


FIG. 24.

therefore, procure an "iron" of the maximum weight that he can handle with comfort.

The "bit" of the soldering iron is made of copper, for various reasons—

1. Properly handled it corrodes but slowly.
2. Solder alloys easily with copper, consequently contact with the copper bit aids solder to "flow."
3. Copper carries a fair quantity of heat from the flame to the work, its specific heat being reasonably high.

A soldering iron is used for heating work to the point at which it alloys with the solder—a mixture of tin and lead in varying proportions. It must, therefore, carry a fair amount of heat, or the tool cools before the work is sufficiently heated, which means the loss of the whole time, for the work cools while the tool is being reheated.

The work being metal, and thus of high conductivity, speed in soldering is of first importance.

The bit of the soldering iron should first be filed clean, at the point or along the working edge. Then it should be heated, in a gas flame, if possible, but the flame should never play directly upon the working part. When the bit is fairly hot—sufficiently hot to cause an appreciable glow immediately when placed 1″ from the face, but short of red hot (at which temperature copper oxidizes readily)—it should be dipped for an instant to a depth of ¾″ into a saturated solution of zinc chloride, and immediately pressed upon a piece of tin plate (an old tin lid answers admirably) upon which lies a piece of solder. Solder and soldering iron are pressed together, in the presence of zinc chloride, when the solder melts, and flows ("runs") along the portion of the copper that has come under the influence of the zinc chloride, leaving the iron ready for use. This "tinning" of the iron should be freshly carried out whenever the bit becomes corroded, or ceases to permit the solder to flow readily.

Pliers.—So many patterns of pliers are now on the market that it is difficult to recommend any one in preference to

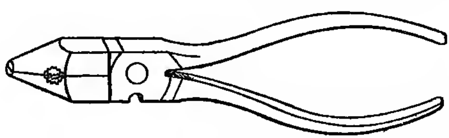


FIG. 25.—"London" pattern, taper-nose cutting pliers.

another. Each pattern has its own advantage, and performs one particular duty with more pronounced success than others. So long as the cutting jaws *actually close*, the design of the other portions of the tool is unimportant. Many forms of cutting pliers, however, only cut thick wire, the cutting edges, when the jaws are closed, being still some distance apart. Pliers with cutting edges and rounded noses are, on the whole, more serviceable than the heavier square-nosed tools, as they are more easily used in a corner. These are known as "London pattern" pliers and are the most generally

serviceable of all. One pair of square-nosed pliers should also be provided.

Drill.—A drill should be available, if possible, of the

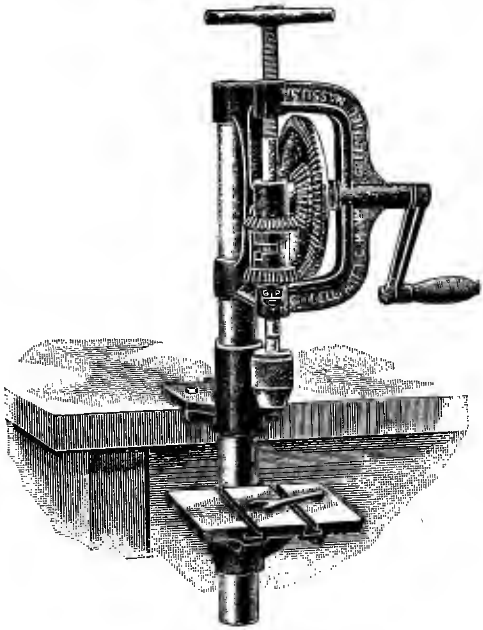


FIG. 26.—Bench drill.

American Bench Drill type (See Adams, page 101, No. $9\frac{1}{2}$, or page 103, No. 18). These drills are very cheap, of excellent quality, and will be found invaluable when delicate work is to be undertaken. A table vice (Fig. 27), as included in the first type, is a most essential accessory.

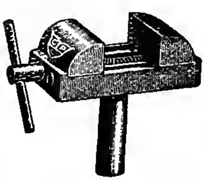


FIG. 27.—Self-centreing vice for drill table.

Failing this, a breast drill of the type shown in Fig. 28, or a hand drill (Fig. 29), should be furnished. All these tools are listed by Messrs. Adams.

Twist drills should be used generally, though wing drills

cut more quickly and give better clearance for waste; but as they break very easily, being generally over hardened, they are

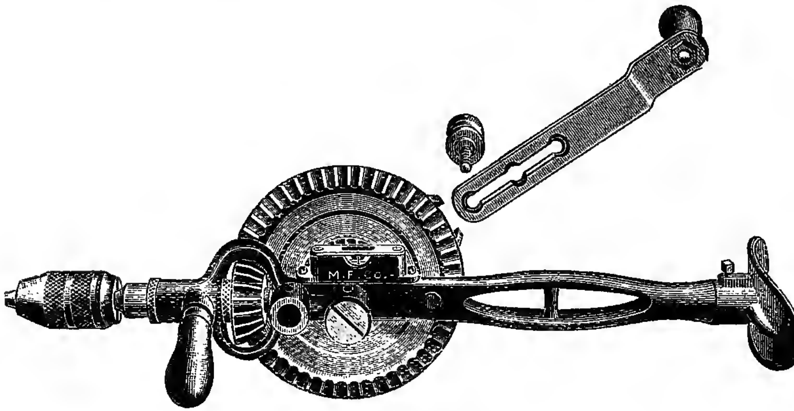


FIG. 28.—Breast drill.

more expensive in the long run. Cases of drills are obtainable from any tool maker accustomed to supply jewellers with tools.

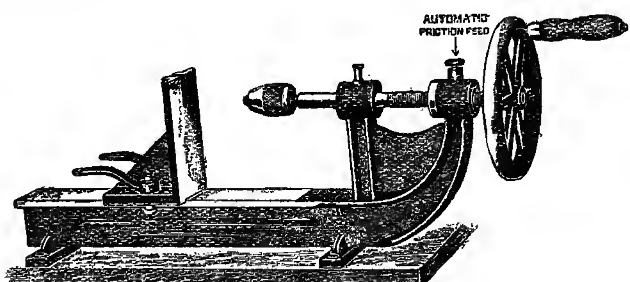


FIG. 29.—Horizontal hand drill.

Jewellers' Turn Screw.—This is a "screwdriver" with loose top, and is held and used as shown in Fig. 30. It is a very necessary tool for taking down scientific instruments. Bits are provided for each size of screw head, and this saves much trouble and a good deal of damage to delicate screws.

Snips or Shears.—One pattern only is in general use—10″ tinman's snips.

Bench Anvil and Vice.—These are not absolutely essential if a good iron-faced vice is supplied for woodwork, but they are a great convenience. Some tools of this type are on the market in the form of combined anvil and vice, but it is best to have them separate, as heavy blows may be struck which will injure the vice if they are combined. The faces of the jaws should remain parallel however wide they may be apart, otherwise there is a tendency to grip work on the two edges instead of on the two surfaces. The anvil may well be of the type known as a "bick iron" similar to those used by dentists. Tinsmiths use similar ones, but much larger.

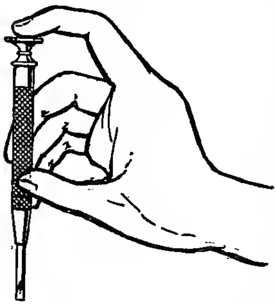


FIG. 30.—Jewellers' turnscrew.

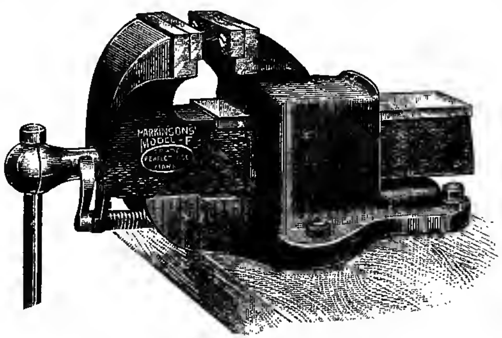


FIG. 31.—Parallel jaw bench vice.

Chisels are of several types according to the work expected of them; as, however, no chipping or heavy chisel work is included in the processes contemplated in this book, it will be sufficient to have a single $\frac{3}{4}''$ steel chisel, which, however, will require re-tempering, those supplied by tool

makers being generally far too soft. The use of this tool will be mainly in the cutting out of sheet metal and similar material. To re-temper the chisel, it is to be made red hot for some distance from the cutting edge, say $1\frac{1}{2}''$ to $2''$ up in order to fully "draw the temper." The cutting edge is then plunged under water to the extent of $\frac{3}{8}''$ or $\frac{1}{2}''$ for 5 seconds, until it is "black," then withdrawn, and the whole flattened face of the chisel rapidly rubbed with sandstone until a clear bright surface is obtained. On watching this surface carefully, a bluish-yellow colour will be found to creep gradually towards the edge, indicating the conduction of heat from the still hot upper portion of the chisel. According to the hardness or "temper" required, this is allowed to proceed, the tool being plunged right under the water when the correct colour (pale to dark blue in this case) is seen. The whole process is one that must be conducted with considerable expedition.

The judging of the colour is the most important portion of this process, and probably some time may have to be spent in the acquirement of the art. There is a danger of cracking the tool if it be cooled too rapidly, while, on the other hand, one must quench instantly the required colour is seen. It is in the judicious cooling of the tool that most skill is needed, and it is a good plan to quench the *whole tool* slightly before rubbing with sandstone, in order to make the temperature difference smaller, and the colour therefore appear more slowly. Even after treatment with sandstone, the whole tool may be immersed in water several times, for an instant only, if the colour shows signs of appearing too quickly. The deeper the colour the softer is the resulting steel. (See also page 62.)

Callipers. — Inside and outside callipers should be separate instruments. Their shapes are well known, and little need be said as to the manner of their use, which is sufficiently obvious. Care should be taken in their use to obtain *average* readings, and not to rely too much upon a single measurement.

Outside Callipers are opened until too wide for the distance to be measured, slipped over the object, slightly closed, and pulled free, at right angles to the axis of the object. Several such readings should be taken.

Inside Callipers are closed until rather too narrow to fit the hole they are to measure, and then opened while in position until they touch the sides of the hole. While outside callipers have broadened jaws, inside callipers would be faulty if so provided, see Fig. 33 A, as they would not measure the diameter accurately. The jaws are, therefore, not infrequently rounded, as shown in Fig. 33 C, or ground to a knife edge, Figs. 32 and 33 B.

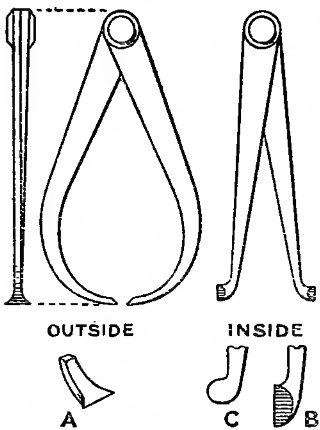


FIG. 32.—Outside and inside callipers, showing various patterns of jaw.

In copying or in comparing two objects by means of either tool, the process is obviously simple, but it is not quite so simple to measure a hole and turn a pin to fit it. Measurements are transferred from one tool to the other in the same way as the measurements were originally taken, only with more care, both tools being liable to alter the distance transferred if carelessly handled.

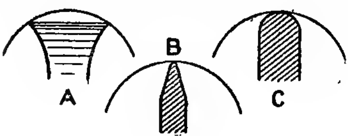


FIG. 33.

If a hole is measured with the inside callipers, transferred accurately and closely to the outside callipers, and a pin obtained to fit this gauge, the pin will enter the hole only with difficulty, even when the edges of pin and hole are chamfered. A "driving fit" would necessitate the pin being of such size that it fits the outside callipers comfortably and easily. Then hammering will drive it home. A "working fit" will be somewhat smaller than this, and should be allowed for in the first setting of the callipers. The difference between a "driving" and "working" fit may be arranged when taking the original

measurement with the inside callipers, a slight lateral play being allowed in measuring for a working fit, whereas a driving fit will necessitate the callipers being only just movable in and out of the hole, of course without "spring." The measurements so obtained are then transferred accurately to the outside callipers, and used as a gauge.

Files.—Large files are not likely to be needed in our work, hence a 10″ flat file (rough) will be sufficient for the heavy work required, and smaller ones may well be—

1. An 8″ half round bastard file.
2. An 8″ hand file (or pottance file), second cut, safe-edge.
3. An assortment of six small key files (Adams, page 120, No. 1 set).

No. 2 will be found the most useful of the group, as the safe-edge permits its use up to a corner.

Files cut by abrasion, and are named in accordance with the coarseness of the teeth. Rough, bastard, second cut, medium, smooth, super (or dead smooth), being the usual terms. Examination of files will be the best way of becoming familiar with these grades.

An ordinary file cuts on the forward stroke only, and should be held with the handle in the palm of the hand, in order that the full force of the stroke may be communicated to the tool. Handles should therefore be selected of such size and shape as will permit this. Frequently one sees chisel handles supplied on files, but tool handles are by no means interchangeable in this way. An uncomfortable handle prevents good work with any tool, and in the case of files this is particularly noticeable.

New files should be used on brass; indeed a new file is almost necessary for this material, but, when worn out for brass, it will still cut cast iron well, consequently it is well to keep a mental record of the history of one's files.

Filing should only be attempted when the object is sufficiently tightly held in a vice to permit the full force of a stroke being made, but instrument makers are frequently called upon to use the file in awkward and constrained positions, consequently no general rules can be given. It should, however,

be remembered that there is a great tendency to "rock" the file when at work, and this should be watched for and avoided. Also, the roughness or coarseness of a file should be suited to the material it has to work. Fine files cut hard materials best, and should never be used upon lead, solder or similar substances.

Files may be cleaned and kept in fair working order with a little care. Cleaning may be done by means of a "scratch brush" consisting of a membrane pierced with many steel wires, such as is used in the preparation of various fibres in textile industries. Should this fail to remove the "dross" choking the teeth, it may be removed by the action of strong nitric acid (for removing brass, tin, solder, etc.) or dilute sulphuric acid (for removing iron), the file being afterwards well washed in hot water, dipped for a few moments in methylated spirit, which is then set on fire. The file by this means is cleaned and dried.

FIG. 34.—"Dreadnought" milling file.

A new type of file is now being placed on the market, known as the "Dreadnought" milling file (Fig. 34). The teeth are portions of a circle, and are machine cut. They may be re-sharpened several times at small cost, and the files act in a "positive" manner, cutting and not scratching the metal away. Probably these will presently take the place of the old files altogether, as they have many advantages, one important one being that they cut all metals equally well, without clogging, consequently may be used for solder, lead, brass or iron indiscriminately. Another great advantage is that they leave the surface ready for finishing or scraping, neither the fine file nor "draw filing" being necessary. These files are somewhat expensive, but as they save other files, as well as time, their first cost is soon repaid.

Stocks, Dies, and Taps.—These should be of Whitworth Standard. Several very convenient sets of tools are now upon the market. One such set is the "Duplex" adjustable

die stock set, with taps. (Hart Manufacturing Co., Cleveland, Ohio.) Its contents enable threads to be cut, and holes to be tapped, of $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}''$ diameter. The cost is £2 12*s.* 6*d.*

Below $\frac{1}{4}''$, screw plates may be used (see Fig. 35), and these

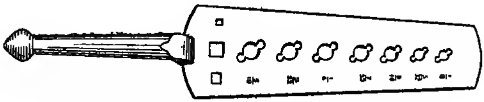


FIG. 35.—Screw plate with tap holes.

should be accompanied by a set of "taps" to fit, or a set of taps may be made from the screw plate. Screw plates may be obtained containing square tap holes, for the tap heads, in addition to the cutting devices, and may conveniently range from $\frac{1}{16}$ to $\frac{1}{4}''$ in $\frac{1}{32}$s. Such a plate costs about 5*s.*

Taps (Fig. 36), which cut threads on the inside of a hole, are of two kinds, "taper" and "plug." The taper tap is inserted first, as it commences the cutting evenly, and the work is completed by passing the plug tap through if necessary. The plug tap is useful in tapping a hole of limited depth, as its diameter is equal throughout, and it cuts full threads immediately on entering. Taps may be made by obtaining a quantity of "silver steel" or excellent quality tool steel, softening in sawdust, turning down to a suitable size, and cutting a thread by means of the screw plate, to a distance of say 2″. The threaded portion is then filed as though it were intended to make a square prism, and some portions of the threads are thus removed. If a plug tap is to be made, grooves must now be cut in this flattened portion.

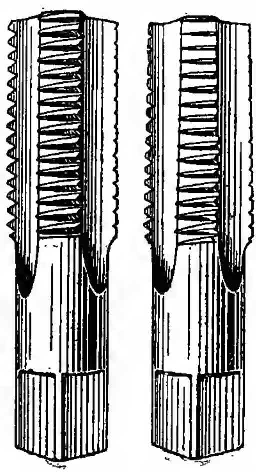


FIG. 36.—Plug and taper taps.

If a taper tap is required, it must first be filed as accurately

as possible in the shape of a long truncated cone, by which means a large proportion of the cut threads will be removed. The total reduction of diameter at the commencing end should not exceed the depth of one thread.

Grooves are then filed with a small round file into the flattened surfaces, deep at the beginning and more shallow at the shank (see Fig. 37); the tap is cut off from the rod about 1″ above the last thread, and is now ready for hardening. This is done by making it red hot, quenching for the full threaded distance and allowing it to become hot gradually through conduction until of a pale straw colour. Then it is quenched fully, and the shank ground to a square section.

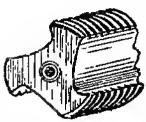


FIG. 37.—End view of tap, showing clearance grooves.

It may be more convenient to file up the shank of the tap to a square before hardening, in which case the hardening is done by placing the tap between two pieces of iron and heating them all to redness, quenching as before.

The making of small taps is rather a delicate matter (for very small ones, the grooves may be omitted), but not of such great delicacy as to dismay teachers of science, and in addition to its being extremely useful, the work of making them is very interesting.

Whenever possible a taper tap should be used first, and followed by a plug tap, as a properly made taper tap has only one or two full threads, consequently though it enters easily, and indicates the threads, it does not fully cut them.

By making taps from the screw plate, one is assured that nut and bolt will fit correctly, as the small amount of "play" that usually comes into being in following out the above method ensures an easy fit.

Taps are driven by "tap wrenches"—plates having square holes which just fit over the shanks of the taps.

Just as the steel to be made into a tap is tapered to enable the screw plate to take up the cut evenly, so should all rods be tapered before cutting screw threads upon them. The taper tap serves a similar purpose upon holes.

In making nuts, the hole should be drilled and the thread cut before any of the metal is removed to form the well-known hexagon, by which means an accurate centre is ensured. Nuts may be then cut by screwing two drilled and threaded discs tightly together (turning one disc slightly backwards) on a threaded rod, by which means they become "locked" and can be dealt with as a solid piece without risk of injury to the thread.

In cutting threads upon rods by means of stocks and dies, it should be noted that the dies being movable, a full thread is never cut at once; the dies are moved apart sufficiently to allow them to comfortably encompass the rod to be threaded, and are gradually closed in as cutting proceeds. The test of completeness is the absence of a "flat" on the outer edge of the thread. This looks like two parallel lines at first which come closer as cutting proceeds, and the thread is complete when these disappear.

In all cutting of threads, a liberal supply of oil should be made use of, and dies should be kept well oiled and cleaned, even while put away.

In no case should thread-cutting tools be used upon steel unless it has been softened or annealed, and it is better to re-soften and make sure, than to use the dies on steel too hard for them, which of course ruins the dies.

III. Exercises in Metal Work.

(1) **Jointing of Wires.** (A) *Uninsulated.*—It is frequently necessary to repair a broken wire, and the method adopted depends largely upon the nature of the break. If plenty of wire remains and one has facility for twisting, the first method will be easy and successful, but if the wire be of fixed length, and unable to be either twisted or half lapped, it will be necessary to employ some such method as No. 4.

Again, soldering may be impossible in some cases, consequently one may be driven to various expedients which will readily enough suggest themselves upon the presentation of the special problem. Consequently it is not intended that this list should exhaust the possibilities—rather that it should suggest standard methods, from which departures may be made as the exigencies of space and material demand.

Note.—Where soldering is to be made use of, the wires should be cleaned with emery-paper before twisting, and they should not be touched with the fingers more than is absolutely necessary.

Wherever the wires are to be used for electrical purposes, resin should be used as a flux, in place of zinc chloride, as this latter necessitates washing the work in hot water, and this is not permissible in electrical work.

Method 1.—Two wires having both ends free. Place the wires so that they overlap at right angles, as shown in Fig. 38. Place the thumb and forefinger of each hand at the intersection, and move each hand in opposite directions, twisting evenly. The commencing point will not be visible if this is correctly done, and the wires will be evenly twisted throughout the joint.

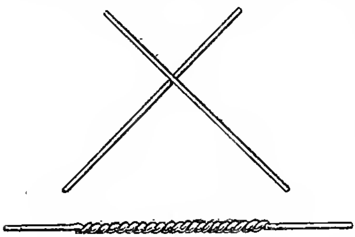


FIG. 38.

Method 2.—Two wires long enough to overlap, but with one end of each fixed.

Grasp the wires at the centre of the overlap with pliers, and coil one free end round the other wire in close coils (see Fig. 39). When this is done, move the nose of the pliers till it grasps the first coil, and repeat with the second free end. The centre will be slightly different from the rest of the coil, but will be sufficiently strong. An alternative method is to place the wires to be joined side by side, and to wind round these, in close coils, a third wire, commencing to wind in the middle of the overlap and the centre of the third wire, gripping meanwhile with square-nosed pliers. The ends of the original wires should finally be turned up, and cut off short with cutting pliers.

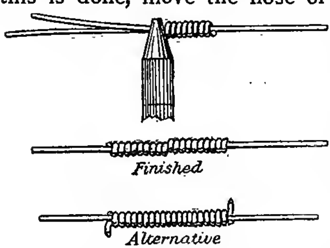


FIG. 39.

Method 3.—Two wires as above, but too stout for coiling.

Clean each wire, and file the ends in a plane, cutting the axis of the wire at an acute angle (see Fig. 40). Place these together, face to face, and bind with thin (No. 32) wire in a close coil. This is best done by laying one piece of the No. 32 wire along the joint, and wrapping it back upon itself, when the two ends are available for "fastening off" by twisting.

Method 4.—Two wires, with ends touching, but not long enough to overlap.

FIG. 40.

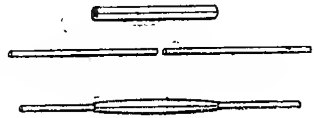


FIG. 41.

Take a piece of copper foil, and roll it round a needle of the same diameter as the wire. Cut about 1″ off this "sleeve," tin the inside well, and ends of the wires. Fill the sleeve with solder, heat strongly over a bunsen, and slip in the end of each wire in turn before the solder solidifies (Fig. 41).

Wires connected at an angle. *Method* 5.—By twisting the second wire in a close coil around the first, a good joint is made; but, if any vibration is likely to disturb the junction, the joined wire will probably break off at A (Fig. 42). For this reason a third wire may be coiled, as sketched.

Wires at acute or obtuse angles may be treated as above, and bent before the third wire is wound on. This will usually be sufficient.

Multistrand Wires. These wires are usually much more easily treated than single ones, as the strain of the joint is divided among the strands instead of coming at one point. Wires of this class have 3, 7, 19 or 37 strands, for the reason that this number is

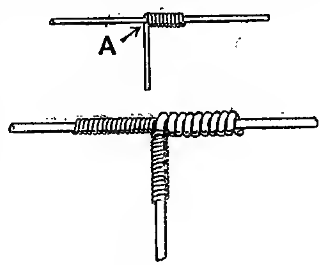


FIG. 42.

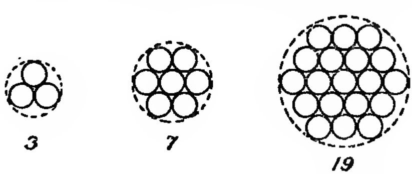


FIG. 43.

the most natural for securing a maximum number of strands in a minimum area (Fig. 43).

Three-strand wires are opened against each other, as in Fig. 44, and the wires of one cable inserted in the spaces between the wires of the other cable; all the wires are then clasped round each other, and twisted as nearly as possible into the original diameter of the cable, the projecting ends being removed by cutting pliers.

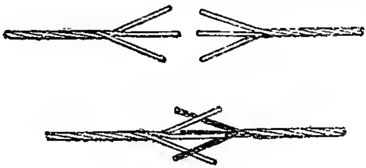


FIG. 44.

Seven- and nineteen-strand cables are similarly treated, but the centre strand is removed first, up to the point where the untwisting commenced. Joints at an angle, in multistrand cables, are made by pushing the wires of the joining cable through the centre of the continuous one (Fig. 45), and wrapping half the projecting strands round the outside of the continuous cable in one direction, the other half in the opposite direction.

A "Flexible lead" should have a portion of its insulation removed, and have all its strands soldered into one solid wire before it takes part in any joint, save where it can be pushed through a multistrand cable, as above.

Mere contact of wires should not be regarded as sufficient.

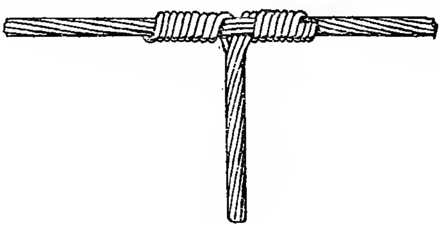


FIG. 45.

Joints should be made so as to withstand harsh treatment, and in order to secure strength, and metallic contact throughout, it is necessary to solder all joints. In soldering, however, a flux is necessary, in order to enable the melted solder to flow easily into the joint, and this flux must be of a non-corrosive nature, so that it necessary it may be left in the joint. The solution of zinc chloride recommended for use when "tinning" the soldering bit would not be suitable in these cases, as it is corrosive, and not easily removed save by much washing in hot water, a method not permitted in

connection with electrical work, as the insulation would be destroyed. Resin is therefore used as flux.

Powdered resin being sprinkled well over the joint, the flame from a blowpipe, or blowlamp, is allowed to play upon the joint until it is well warmed up, when the joint is touched with a strip of soft solder, also dipped in powdered resin. If a suitable temperature has been attained, the solder will run into the joint without further trouble. A soldering iron is of little use in the jointing of cables, as the cable conducts the heat away from the joint as quickly as the iron supplies it, but when a joint has been "sweated" as above, it may well be trimmed with a soldering iron. Files should not be used for trimming; all soldered joints should be sufficiently clean from the iron, and it should be remembered that one test of excellence is how *little* solder can be used to make a perfect joint.

Resin is not so easy a flux to work with as zinc chloride, the tendency being to apply it too soon and ignite it, when it blackens the joint, which consequently needs freshly cleaning.

A great deal of trouble occurs in soldering through not using a sufficiently high temperature. It should be remembered that the temperature of the solder is of secondary importance; it is the work that must be hot, and as the soldering iron usually supplies the heat by conductivity of the solder, the solder is generally well melted when the work is still too cold for the solder to flow. When the work is hot, however, the solder runs in quite easily, being kept up to temperature by the work itself.

A little practice with the iron will soon convince a student that soldering is an easily acquired art, and he will be rewarded by the production of neat and smooth-surfaced "jobs," instead of the heavy *mainly solder* productions of the early stages.

(B) *Insulated.*—Cables such as those treated of above are usually insulated, and this insulation must be replaced after soldering, except of course, in the case of "flexible" (*e.g.* 55 strands, No. 32 wire), which need not be so treated as a rule.

Insulation generally consists of four layers—

1. Pure unvulcanized rubber laid on the wires.
2. Vulcanized rubber, one or two layers (if more than one, a difference in colour is made to indicate the number).
3. Spiral tape, soaked in rubber solution.
4. Woven jute wrapping, impregnated with a bitumenous composition.

The insulation must be removed in successive layers, exposing about an inch of each, and leaving sufficient wire or cable exposed

to permit the making of the joint as already described. Great care must be used in cutting the last layers of insulation, as a nick in the wire will generally cause fracture there.

After jointing, sweating, and trimming, the whole is cooled, the joint well rubbed with rubber solution, and wound spirally with

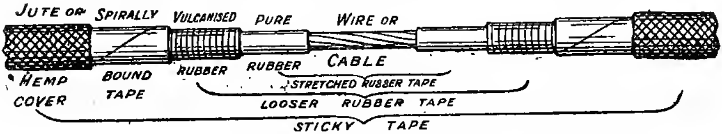


FIG. 46.—Showing layers of insulation and cable ready for jointing. The extent covered by successive wrappings of fresh insulating material, after jointing, is also indicated.

rubber tape, with considerable tension upon it. This will replace the pure rubber insulation, the most effective of all. It should overlap the next layer about $\frac{1}{8}''$ to $\frac{1}{4}''$. The upper surface of that already wound on is next smeared with rubber solution, and the winding continued with the same material, but with much less tension, again overlapping the next layer by $\frac{1}{4}''$. The end of the rubber strip being held, a quantity of "sticky tape"—ordinary tape soaked in bitumenous rubber compound—is spirally wrapped along the joint until the whole is of the original diameter, and the ends of the hemp covering are enclosed in the final wrapping. This tape adheres without additional treatment, and the free end may be left simply pressed against the underneath layer.

The rubber and "sticky" tapes are most serviceable when $\frac{1}{2}''$ wide. They are sold by weight. Chatterton's compound may be found useful in finishing these joints, especially when the joints are exposed in damp situations. Chatterton's compound is applied hot, like sealing wax, and may be moulded into any desired form by the fingers, to which it adheres excellently unless they are frequently dipped in cold water, or smeared with powdered chalk.

EXERCISE 2.—*To make a box to hold 1 cubic inch. This may be constructed in sheet brass.*

On a sheet of thin brass, the development of a cube is to be drawn by means of a sharp instrument, *e.g.* a steel knitting needle well ground to a very sharp point. The plan may be either of those shown in Figs. 47, 48. Allowance must be made for the thickness of the metal, and for flanges which will be subsequently soldered.

These may be added wherever necessary, clearance pieces being cut away, as required. The box is then roughly cut out, either by snips or chisel ; if the latter be used, the brass must be supported on some heavy substance—*e.g.* a block of iron—while being cut out. The roughly cut sheet is heated to redness, quenched in cold water to soften it, and cut out exactly to shape. (This softening may be done before the marking out of the box, if more convenient, but as it usually entails making a much larger piece hot than necessary, or else a waste of material by the cutting of very roughly approximate shapes, the sequence above given will prove, as a rule, more economical). The flanges are then bent into the required shape by hammering over the edge of the anvil, or by grasping the metal in a vice (the flange only projecting), and hammering down flat.

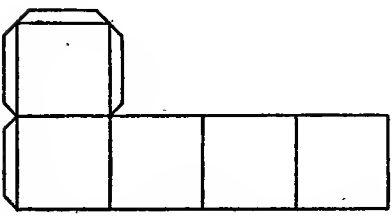


FIG. 47.

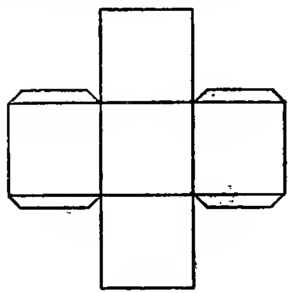


FIG. 48.

The edges of the box to be bent should now be scored by a scribing tool (an old knife with a broken blade answers this purpose admirably), on what will be the outside of the box, and the edges bent as before. Previously to making the box complete, the whole of the inner surfaces of the flanges, and the outer surfaces of the box, should be well cleaned with emery-paper, and care should be taken not to finger-mark these, or they will be difficult to solder, and equally difficult to clean.

If the plan shown in Fig. 47 be adopted, the flanges may be turned on the outside of the box, by increasing the dimensions of the base by the thickness of the metal on each side, in excess of the geometric proportions, when scoring before bending. Similarly if Fig. 48 be adopted, the flanges should be scored for bending in a line outside the constructed squares by the thickness of the material.

Under these circumstances the box should be easily and

accurately bent into shape, and it will be found useful to have a small piece of iron rod $\frac{3}{4}''$ square filed to square edges, upon which to shape the box in case of difficulty.

Having bent the flanges into shape, and made up the box, paint a little zinc chloride solution on each joint, taking care that it runs well into the various joints, and by means of a hot, well-tinned soldering iron, stroke the joints in turn, supplying solder in the form of a strip when necessary. *Do not use too much solder.* There will be endless trouble in making a neat joint if too much be used, and if the soldering iron has already one small bubble or bead of melted solder upon it, and is used sufficiently hot, this will be enough to complete the box.

Before the solder completely sets, in each case, the joint may be squeezed by pliers, and so held till cold (meanwhile proceeding to the second joint), from which it will be gathered that method (2) will make the neater job.

The box should be washed well in boiling water, shaped if necessary on the iron plug as above, and tested by weighing empty, and full of water. If the box is correctly made, the difference will be 16·4 grams.

A subsequent useful exercise may be the making of a 1 c.c. box.

EXERCISE 3.—*Three-way plug-key.*

The base for this instrument has already been prepared (see Woodwork, Exercise 2), and we are thus provided with a vulcanite plate, mounted on teak of suitable size for our work.

Take a strip of brass, $\frac{1}{2}'' \times \frac{1}{4}''$ section, $5''$ long. Cut this with a hack saw into three pieces, one $2''$ long, and two $1\frac{1}{2}''$ long. Face up these pieces, and solder them together as shown in the sketch. Drill[1] two $\frac{1}{4}''$ holes in the centre of the soldered pieces at XX, resting the material meanwhile on a spare piece of wood, in which nails may be driven to hold the brass in place. Drill also two $\frac{1}{8}''$ holes in the long piece as indicated at AA, Fig. 49, and one similar one in each of the smaller pieces, $\frac{1}{4}''$ from the end, in every case. Also a $\frac{1}{8}''$ hole in the centre of the $2''$ piece. Underneath the brasses, at points BB, $1''$ from the free ends, drill a $\frac{1}{16}''$ hole three-sixteenths of an inch deep, and into these solder $\frac{1}{2}''$ pieces of brass wire, well straightened to form "steady pins" when mounting. Two further $\frac{1}{8}''$ holes, $\frac{1}{4}''$ from the soldered ends, may also be drilled.

[1] Drilling must always be preceded by marking with a dot punch or centre punch, in order that the drill may enter where it is intended to.

These holes and the two holes AA in the 2″ piece should be countersunk, either by using a larger drill, or by a metal countersinking tool, resembling a wing drill, but sharpened to the screw head angle.

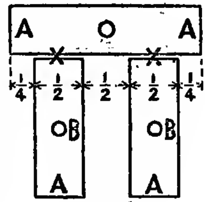


FIG. 49.

The metals may now be placed down on the base board, their positions marked, and the holes scribed round with the knitting needle used in the previous exercise, unsoldered, and thoroughly cleaned and faced, about $\frac{1}{32}$″ being removed from the tinned ends of the smaller pieces. The several pieces should be finished by "draw filing," and by rubbing on fine emery-paper, when they are ready for lacquering. This may conveniently be done by heating them over a bunsen until just too hot to handle comfortably, dipping them into a clear solution of shellac in methylated spirit, and brushing off the excess by one or two strokes of a camel-hair brush. Usually they will dry evenly; if not, the process must be repeated, from the emery-paper stage. The brushing must be done quickly and firmly, a single stroke only should be required on each surface. When quite dry, the metal may be heated again, either in an air oven or over (not *in*) a bunsen flame, until the desired colour is reached, any shade being obtainable from pale straw to black, according to the temperature to which the metal is raised. Once the shellac is dry it must never be touched with the fingers until "stoved" or "coloured" and cooled, otherwise finger-marks will remain.

Mounting may now be proceeded with. The vulcanite is to be drilled under all the holes in the brass, and under the steady pins.

By means of a bradawl the wood is pierced for screws under the countersunk holes, and all is now mounted by means of brass screws, care being taken to drive these well home, using the turnscrew *vertically*, in order to prevent damage to the screw head. There should be a space between the large and the two smaller pieces of about $\frac{1}{32}$″.

The terminals have now to be fixed, and these may either be made by soldering $\frac{1}{2}$″ or $\frac{5}{8}$″ brass blanks into round-head brass screws (see Fig. 50), or bought terminals may be used, in which case, however, their bases should have been soldered to the brass bars before lacquering.

Three terminals are required, one for each small piece, and one for the centre of the larger piece of brass.

Finally, the plug is to be made. For this purpose a piece of

$\frac{3}{8}''$ round brass $1\frac{1}{2}''$ long is required, and half this should be filed taper to slightly under a $\frac{1}{4}''$ diameter (Fig. 51). This will be more easily done on a lathe, of course ; failing this, the brass rod should be held in the left hand and rotated in an inclined direction on a

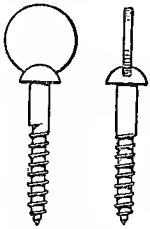


FIG. 50.

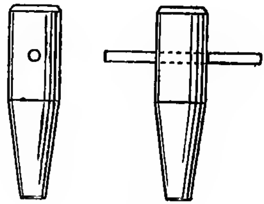


FIG. 51.

wooden support, one end only of the rod touching the support, the file being used in the ordinary way, on the rotating rod. Care must be taken to keep the rod rotating one complete revolution in order that the taper may be symmetrical, and if this be done little difficulty will be found in tapering the plug correctly. It is filed in this way until it enters each hole and makes good contact without rocking. When this is the case, the plug is fitted with a brass wire handle, smeared with emery powder and lubricating oil, and ground into its place by a spiral twisting motion, the emery being renewed frequently. The plug will gradually wear away from the mounted brass pieces a place for itself. The plug should be frequently changed from one hole to the other, in order that both holes and plug may arrive at the same shape together. As soon as the plug fits well, and without shaking, the grinding may be discontinued and the instrument cleaned up.

If the terminals sketched are used, they will not be in the way of the plug, but bought terminals may, consequently it is well to make sure of the sizes before cutting the plug.

EXERCISE 4.—*Tin plate condenser jacket.*

Tin plate is not a good material to use for this purpose, but one can frequently make one up more quickly than in glass, which takes a long time to anneal, and even then is usually more fragile than a tin one. Copper, of course, would be a superior metal, and may be treated in exactly the manner indicated below, a permanent and useful piece of apparatus being thus obtained, whereas a tin-plate jacket only lasts a short time before rusting. Tin plate,

however, is cheap and easily obtained, which cannot be claimed for copper.

A piece of tin $3\frac{1}{2}'' \times 7''$ has its two $7''$ edges turned up in the same direction, one $\frac{1}{8}''$, the other $\frac{1}{4}''$, a line being scored down to assist the bending. The plate is then wrapped round a broom handle or similar mandrel, and shaped with a mallet into a cylindrical tube, having two projecting flanges, one $\frac{1}{8}''$, the other $\frac{1}{4}''$ high (see Fig. 52). The larger one is now to be turned over upon the smaller, a matter of some little difficulty without the tools of a tinsmith, but success will be achieved by a pair of square-nosed pliers, dealing with a small portion at a time, or the flange may already have received its shaping before the plate was bent round. The flange having been bent at right angles, it is next hammered over against the edge of the anvil, and a tight joint made (Fig. 53).

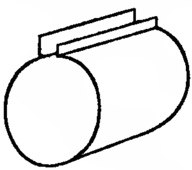


FIG. 52.

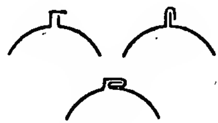


FIG. 53.

The cylinder is now transferred to the original mandrel, upon which it should slip easily, and the flanges flattened with a light mallet. Solder may then be run down the groove with a soldering ron in order to make the joint watertight, but this should not be necessary. The inlet and outlet tubes are made from $2'' \times 1''$ strips of tin, rolled round a lead pencil or similar mandrel, and allowed to overlap $\frac{1}{8}''$, solder being used to hold these together.

Holes are now punched or cut in the condenser jacket (while on the mandrel) somewhat smaller than the tubes, and then enlarged by cutting back radially and bending up in such a way as to provide flanges for the tubes, which are inserted and soldered in. Trouble may be experienced in keeping the tube tightly held together while soldering in, and, as an aid, the tube may be meanwhile wrapped with thread or fine wire, which is, of course, removed when the job is finished. It is necessary to have the tubes a good fit for the holes, as it should be remembered that solder is but a cement, and joints should never be "moulded up" in solder except with fixed purpose, in special cases (as, *e.g.*, in dealing with lead, which needs extra support). Solder will never make a badly fitting joint into a sound job; it is not meant to hide defects

in fitting, and all the joint should be visible through the slight "skin" of solder used to fix the materials finally. In addition, it may be noted that a well-fitting joint takes the solder without trouble, while an ill-fitting joint is exceedingly difficult even to make watertight.

IV. Additional Metal-work Processes.

Riveting.—Rivets are used for joining metals where soldering or brazing is impracticable, or where these joints would not be sufficiently strong.

Rivets are usually made of copper or malleable iron; wire nails (French nails) make excellent rivets for many purposes, though copper is to be preferred. Contrary to general opinion, riveting is a simple process, and one easily accomplished, the only trouble being in the drilling.

Rivets may be made from copper wire (No. 16), or from wire nails, or they may be purchased generally from saddlers or ironmongers. Washers usually accompany them, but these are not absolutely necessary, unless the material to be riveted is soft, when a washer is, of course, indispensable.

In making a lap joint of metal, rivets should, if possible, be put in in two rows, "staggered," as shown in Fig. 54, this giving greater security from cracking than if they were all in a line. In riveting strips of metal together, washers are not necessary, but sometimes make a more satisfactory job, as they take all the strain of hammering.

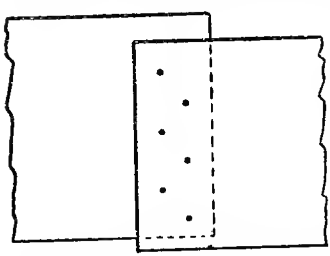


Fig. 54.—Positions of rivets in riveted lap joint.

The necessary holes having been drilled, a rivet is slipped into place, and held upon an anvil, while the tail of the rivet is hammered into shape. This tail should not project more than $1\frac{1}{2}$ to 2 diameters above the hole, and the rivet should fit the hole tightly, or it will bulge, and tend to separate the plates.

The flat pane of the hammer is used at first in riveting, the tail being hammered lightly across the top from A to B, Fig. 55, until a somewhat flattened head is made upon it, when it may be hammered more heavily, and finally flattened to the surface of the joined plates. During hammering, the plates should occasionally be struck in order to ensure that they do not "creep" up the rivet, and it is well also to watch that the rivet head and plates are touching all the time.

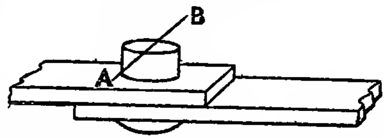


FIG. 55.—Rivet in position ready for closing.

No difficulty is to be anticipated in making use of this process with success.

A word may be said with advantage concerning the repair of china by "riveting." Though badly named in this connection, a metal stay is frequently of great service in the union of porcelain, as a supplement to a cemented joint. To make this, a hole is drilled (see Glass Drilling) well into the china article, about $\frac{1}{2}''$ from the joint, and a piece of hard copper wire (or better still, tinned iron wire), No. 18 about $1\frac{1}{2}''$ long, is bent very sharply at right angles, $\frac{1}{4}''$ from each end. This wire is then placed at right angles across the proposed joint, and the ends cut down until, when one end is put into the drilled hole, the wire lies flat on the article. A second hole is then drilled in the china, opposite the first, a shade out of reach of the wire stay—the exact amount being learned only by experience, it is really the maximum the wire will stretch,—so that when drilled, the stay may be sprung into place, and will actually pull together the broken surfaces. Several such stays are prepared, not less than three as a rule. The broken edges are then treated with a suitable cement, placed together, the stays inserted, and the remaining spaces in the drilled holes at once filled with plaster of Paris.

This method is equally applicable to glass.

Brazing.—This operation is one not usually conducted in the laboratory, owing to the difficulty of securing sufficient

heat. Small jobs, however (keys, etc.), may be easily brazed on a charcoal hearth, with a No. 5 Fletcher blower and laboratory blowpipe. For this purpose make a sheet iron trough, as shown in Fig. 56, by bending up a piece of ordinary sheet iron, and fill it with pieces of compressed charcoal such as are used for blowpipe analysis, or coarsely powdered hard gas coke, of about ½″ cube. Rest this on an asbestos millboard, and heat up.

Place the job on the hearth in position and rake the charcoal well round it. Smear the proposed joint with a paste of powdered borax glass[1] and water, and heat up to red heat, keeping the charcoal well heaped round the work. By means of an iron wire flattened at the end, Fig. 57, sprinkle

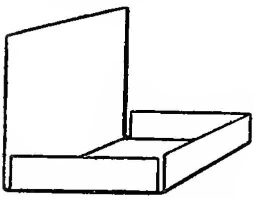


FIG. 56.—Iron plate brazing hearth for small jobs.

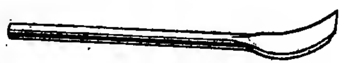


FIG. 57.—Spoon for adding flux during brazing.

a little white brass filings ("Spelter") on the joint, and continue heating until it "runs." More borax may be necessary; if so, it should be added dry, and more spelter then thrown on the work. When the correct temperature has been reached, and the brass has "run," the hearth may be cooled down, and the job withdrawn. The work will usually require to be filed up, and when first withdrawn will not have a very attractive appearance.

Copper may be brazed to copper, copper to iron, iron to iron, but brass cannot usually be brazed, the job melting at the same temperature as that required to melt the spelter.

Spelter is made from soft brass; fine brass wire cut or filed up makes good spelter, indeed brass wire may be used by

[1] Crystallized borax, which has been heated until all the water of crystallization is driven off.

wrapping the joint with it before brazing and melting this in simply adding the flux as required.

Welding.—The welding of iron or steel is a process which may be considered as outside our work here, but the welding of platinum, being so easily performed and so useful an accomplishment, may well be described.

The most simple method is to arrange a foot blowpipe so that its flame plays downwards upon the metals to be united, which should be supported upon some incombustible and perfectly steady support, *e.g.* a bench anvil, the face of which is covered with a brass or copper sheet, in order not to injure the anvil by the direct blowpipe flame.

One piece of the platinum being so placed in position, the second piece to be joined is held over the first, and the blowpipe adjusted so as to heat both conveniently, with the smallest flame that will do the work. When the upper piece is well above red heat, and the lower piece red hot, a single smart blow is struck with a light hammer, the blow causing the two pieces of platinum to come into contact under pressure before the heat is dissipated. Usually a single blow, if delivered vertically, will be sufficient to cause perfect union, much hammering of the soft metal being, of course, a disadvantage. In any case, a thorough examination should be made of the joint after each blow, and the next blow very carefully planned. After union has occurred, reheating is best attained by lifting the job slightly off its support; the next blow of the hammer will press it down with sufficient rapidity to cause no loss of heat through this action.

The blowpipe flame should not be removed until the welding blow has been struck, as the metal would cool too quickly in such case.

Wires may be welded end to end by flattening each end out slightly, superposing one flattened end above the other, and welding as above, subsequently hammering under heat if necessary into cylindrical form.

Case-hardening.—This is the process of hardening the surface of an iron forging to give it wear-resisting qualities. On a large scale, this process can only be performed in properly

constructed furnaces, but small jobs, such as small bearings, may be case hardened with sufficient precision for laboratory purposes in a very simple way. Case-hardening simply consists of altering the composition of a forged iron surface giving a very hard and wear-resisting "skin." This is brought about by the addition of carbon. An article to be case-hardened is heated to redness in the ordinary fire and immersed momentarily in a pot containing powdered yellow prussiate of potash, or sprinkled with the prussiate. This becomes melted round the red-hot metal, and in cooling re-solidifies and is chipped or washed off, the process being repeated according to the depth to which hardening is desired. The iron is finally heated to a full red heat, and quenched in water, when it will be found to have acquired remarkable hardness on the surface, without being so liable to crack as a steel forging would be. Wrought iron, forged, and case-hardened in this way, may be used for the making of lathe and other tools in cases of emergency.

Silver Soldering.—For this process, which is used in cases where a very strong joint is required, proceed exactly as for soft soldering, so far as the cleaning of the surfaces is concerned. Then place in position and cover the joint with powdered borax and heat till the first action ceases and the borax melts quietly.

Sprinkle over this a few filings of "silver solder" (2 parts standard silver, 1 part brass wire, melted together) and heat with a small blowpipe flame, till the metal "runs" into the joint. If more solder be required it should be added in the form of a cream of solder filings, powdered borax-glass, and water, and heated up again as before.

If the joint is required to be very hard, as well as strong, the silver solder employed should be composed of three parts by weight silver and one part brass.

Tempering Steel.—The tempering of a steel chisel has already been dealt with, but it is necessary to give rather more detailed instructions in order to cover all the examples that may be met with in laboratory work.

It is not always possible to make use of the most direct

method in laboratory work. The object may be difficult of access or it may have attached to it some combustible material not convenient to remove; consequently one has to exercise considerable ingenuity in the accomplishment of one's task. In one actual case, for instance, the steel pin of an air pump pinion had to be re-hardened while in position, surrounded as it was by rods, barrels, and pillars. This was attained by polishing, touching with a hot poker till the correct colour appeared, and quenching by means of a jet of water from a wash bottle. Difficulties such as this are of everyday occurrence to the repairer of scientific apparatus, and they may usually be disposed of by the exercise of a little imagination and ingenuity. Any one who has estimated bromine in the presence of nitrates and iodides will have little trouble with mechanical difficulties. The following suggestions may be of use.

Before tempering steel, it is necessary to "draw" the temper completely by heating to a full red heat for a few minutes, and subsequently cooling rapidly. This makes the metal very hard. It is then heated up a second time, and tempered. The method of doing this greatly depends upon the article to be tempered, a chisel or heavy solid which retains heat for some time being treated as already described on page 41, but a watch spring obviously cannot be so treated. Such a spring would be heated, cooled quickly by dropping in water, and then polished. An iron plate, sufficiently large to take the whole spring, would then be made red hot, held above a bucket of water, and the spring dropped upon this plate. When the spring became purple, it would be dropped off the plate into the water, and so be tempered correctly. The success of this operation depends upon the accurate contact of the spring and plate over the whole surface covered by the spring. Small twist or wing drills may be similarly treated. Flat springs may be treated by first hardening, smearing over with tallow, attaching a wire about a yard long to the spring, and putting in a fire until the tallow has just burnt off completely, then withdrawing sharply and swinging round in the air until cold. Penknife blades may be tempered similarly.

Various mixtures are recommended for quenching, from

ammonium chloride to animal refuse, but clean water appears to be as suitable as any; save perhaps in the case of dies for stamping metal, punches for metal, etc., which may be finally quenched in oil (the kind does not appear to matter much). Oil, having a high boiling point, continues in contact with the metal till quite cold, whereas water is converted into steam near the hot object, which is thus surrounded by a steam jacket and cools more slowly. The main object of the addition of sulphuric acid, salt, salammoniac, etc., to the quenching water, appears to be that of raising its boiling point.

The following list of temperatures suitable for tempering steel articles will be useful—

220° C., pale straw—dies, punches, taps, glass or china drills, needles, lancets, small drills, cold steel chisels.

245° C., dark yellow—razors, scalpels, twist drills.

250° C., dark straw—penknives, wood drills.

255° C., clay yellow—chisels and shears, centre punches.

260° C., brown yellow—plane irons.

270° C., very pale purple—table knives, arbors, pins.

275° C., light purple—watch springs.

290° C., dark purple—softer springs.

310° C., dark blue—fine saws.

320° C., pale blue—large saws.

330° C., greenish blue—tools of very mild temper.

As lead melts about 335° C., it will be seen that after hardening, steel may be given a very mild temper by being immersed in melted lead, and quenched in water.

Uses of Studs.—The word "stud" is applied to a steel rod having threads in opposite directions cut from each end, separated by an unthreaded portion. It is screwed into a solid up to the point where the threads cease, then plates or other portions of mechanism may be bolted to the solid by means of a washer and nut travelling the projecting thread.

Studs are made by screwing first one end and then the other of a short rod (previously measured to suit its purpose), the space between the two threads being determined by the thickness of the material to be bolted to the solid.

To prevent injury to the first thread while cutting the second, the stud is held by a nut of its own size, which has been cut into two pieces, and clamped in a vice, the width of the saw cut providing sufficient space to secure a tight hold.

Studs are screwed home by screwing a nut down upon the top thread, and a second nut down upon that, backing the first one slightly upon the second when they touch. By this means the two nuts become "locked," and the spanner will not move either until the stud is screwed home. By putting a spanner upon each nut, and pulling in opposite directions, these may then be separated and removed.

In any position where vibration is great, all nuts should be locked by a second when screwed home. This is better than drilling the bolt and putting a split pin through above the nut, as this simply prevents the nut from falling off, not from "slacking." Many good locking devices are now upon the market, split spring-washers, castelled nuts[1] and split hexagonal trough washers, set screws, and many other equally serviceable and ingenious arrangements, developed mainly by the growth of autolocomotion, but this is not the place for a lengthy discussion of such devices. The second lock nut, or a castelled nut and split pin will be found to answer practically all the purposes desired by instrument makers.

V. Finishing of Metal Work.

The finishing of a piece of filed work is important. From the file the material is left with its surface more or less roughly scratched; this is to be removed. The removal is accomplished by the use of progressively finer files in trueing up the surfaces, the last file leaving a perfectly plane surface. To secure

[1] In the castelled nut, a hole is certainly drilled through the bolt, but the top of the nut projects, and has three slots cut across it, into any of which the split pin may go, and as the nut is slotted for about three threads, the single split pin locks the nuts for a considerable number of points. Should the nut proceed up the thread in the course of time, sufficiently to render the split pin ineffective, an extra washer is slipped under the nut, and this restores the device to usefulness.

perfect freedom from file scratches, a fine file may be grasped at each end, and pulled backwards and forwards across the material, the file thus working at right angles to its true cutting direction. This is known as "draw filing," and under this treatment the surface rapidly becomes smooth and polished, the result being much superior to that produced by use of emery-paper. This latter should only be used wrapped round a file or other similar plane support, in order to keep the surface true.

Files may be filled with chalk, and then used upon metals in finishing. This method of use is principally of value in dealing with iron or steel.

A fine surface having been produced, it may be polished with flour emery and lubricating oil spread upon brown paper supported upon a true surface, and finally with rouge and water, or rouge and olive oil.

This, however, applies only to plane surfaces, curved ones not being amenable to such treatment. Curved surfaces are treated with similar materials while being rotated in a lathe if possible, otherwise they are treated by hand as well as may be.

Brass, gunmetal, and platinum may have their surfaces "finished" by burnishing, an easy and pleasing process. Having brought the surface "up" as far as possible by files and emery, a smooth steel or agate burnisher is rubbed with considerable force along the surface producing a bright line; this is repeated until the whole surface becomes bright, the marks of the tool being gradually removed by repeatedly crossing the direction of its motion. Platinum crucibles and dishes should be filled with plaster of Paris before this treatment, when an annual burnishing will be found to lengthen their life considerably, and to render them less liable to attack from a carbonizing bunsen flame.

VI. Miscellaneous Notes.

Wood or metal screws that have become too firmly fixed through age to be withdrawn in the usual way, are frequently loosened by holding a red-hot poker to their heads for a minute or so. After

such treatment they are usually amenable to withdrawing by turn-screw or wrench.

Metal studs or screws that have rusted in may usually be removed after a day's soaking in paraffin oil. Screws that are in important positions, but have become worn or partially stripped, may be temporarily rendered workable by "burring" the threads. This is done by withdrawing the screw, placing on an anvil, and giving it a light tap with a hammer across the threads. These are thus closed up slightly, and the screw, if of soft metal, loses its cylindrical shape, and so fits a portion of its aperture tightly. This is, of course, a temporary expedient only, as once advancing the screw generally brings it back to its old state, and the only real cure is a new screw. The above method will, however, be useful in cases of emergency.

Similarly, a stripped nut may frequently be made to continue useful duty by delivering two blows simultaneously upon opposite faces with two hammers. Stripped union nuts, *e.g.*, may frequently be remedied by this means, as stripping is often due to squeezing outwards rather than to the actual removal of the whole thread.

Fine wing drills may be made with success from good knitting needles, which are, when well made, about the right temper. Drills so made by grinding on a wet grindstone cut brass excellently, and wood, vulcanite, amber, and similar materials, with great ease. The drills should be first ground on opposite sides to a taper, and then the necessary clearance for waste material ground out. The cutting edges are next ground in, and, with care, the clearance for these may be given at the same time. The finished drill will look like sketch. The clearance angle is 5°, and the angle between the cutting edges may be between 100° and 120°.

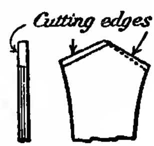


FIG. 58.—Tip of wing drill.

Cast iron, brass, and gunmetal should be drilled with a dry drill, but steel, either mild or hard, should always be well lubricated with oil, or the temperature of the cutting tool will rise beyond that at which it was tempered, and the drill consequently become soft.

Broken iron rods may be mended by thoroughly cleaning and polishing the ends, and preparing an iron tube or sleeve that will comfortably slip over the cleaned ends. A finely powdered mixture of fine iron filings and ammonium chloride is then moistened, smeared over the two ends, and the sleeve fixed on one end. The

sleeve is then partly filled with the above mixture, and the second end placed in position. In a day or two the joint will be rusted tight, and it will be impossible to move the parts. This method is applicable to a broken iron water pipe, or cast-iron water jacket, indeed to any broken iron article where the mechanical difficulties arising from its use are not insuperable.

SECTION III

GLASS WORKING

GLASS is the commonest material in use in laboratories. Apparatus of all kinds is constructed of this material, and by many and various methods is it fashioned to our use.

Roughly, we may say there are three kinds of glass used; each, of course, capable of some subdivision.

A. *Bottle glass:* Fine white (flint), green or blue.

B. *Sheet glass:* Window or photographic glass (crown), plate glass, "patent plate."

C. *Glass rod and tubing:* Lead glass, soda glass, hard glass, combustion (and Jena) glass.

Though we have so many varieties, the methods of working fall mainly into two groups—

(A) Cutting, grinding, and drilling.
(B) Bending and blowing before the blowpipe flame.

SUB-SECTION (A)

CUTTING, GRINDING, AND DRILLING

1. **Cutting Glass.**—Window glass is used for making up lantern slides, screens for various purposes, cells, covers, specimen holders, etc.; and, as it is purchased in sheet, our only business with it is in the matter of cutting and shaping. The glass used for photographic plates is specially selected for its plane surface, though it is only of ordinary quality. Stripped negatives, therefore, are a valuable source of this material. Window glass is cut most satisfactorily with a diamond, though few laboratories possess such an instrument. Failing this, an

American tool with a wheel cutter of glass-hard steel is fairly efficient when new, and is much cheaper. Failing this again, a freshly broken file will be found to cut glass reasonably well, but much more care has to be exercised in making sure that the glass has been cut, not scratched, before attempting to break it.

A diamond really cuts the glass right through, although it touches but the surface, whereas in using either of the other tools it seems necessary to remove some of the material, and make a **V** in the surface, along which the glass naturally cracks under strain.

No difficulty will be experienced in cutting window glass with a diamond—one has to be careful to make a true cut from the start; for even a diamond, wrongly used, will tear the glass, much to its own detriment. The cut having been made, the glass is broken by placing the thumbs on the upper side of the glass, the fingers underneath, one hand on each side the cut, and pulling rather than bending the glass apart—much the same action as though one were trying to bend the glass at the far end of the cut.

Patent plate should be first cut, as above, on a table of green baize or similar soft material, then turned over and tapped smartly along and above the cut, which has the effect of bringing the cut through. After this it may generally be broken apart with ease and certainty.

Plate glass is treated similarly. As the glass is heavy, it is a good plan to slip a rule under the glass touching the cut (which in this case should be on the upper surface of the glass), and press sharply down on the other piece about the middle of the cut.

Both plate and "patent plate" are expensive, and it is well to practise upon some old pieces before attempting anything important. Usually a special diamond is kept for plate glass.

Should it happen that glass must be cut with a file, choose a fine rat-tail, or small triangular "saw" file, snip off the end as close as possible so as not to injure the file, and try point after point until one is found which really cuts. Then cut by

drawing this point across the surface against a steel rule. If the point is not really cutting, and only tearing the surface, it will probably crack the glass on overshooting the edge, so that it is well to stop before actually reaching the edge, until certain the instrument is cutting. With a diamond one may tell by the sound when cutting is taking place, and it is only necessary to ease up at the edge for the sake of the diamond. The glass is severed as before.

Cutting down broken Winchesters, etc.—Frequently broken stock bottles may be cut down to make useful jars or other appliances with very little trouble. A Winchester quart bottle with a broken neck, which would be ordinarily discarded, may, for example, be usefully employed as a jar if cut off halfway down, while a similar bottle broken at the base may be used either as a rapid filter, Fig. 59, or as a bell jar, by cutting off and grinding past the broken portion.

The method of performing this is as follows: A strip of brown paper 2″ wide is wound round the bottle, until three thicknesses surround it immediately above the point where the cut is desired, see Fig. 60. About $\frac{1}{8}''$ away from this a similar

FIG. 59.

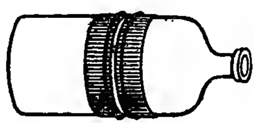


FIG. 60.—Winchester quart bottle prepared for cutting before the blowpipe.

strip is wrapped, and each strip tied tightly near the inner edges with string. The whole is then dipped vertically into a bucket of water, until the paper is thoroughly saturated, taken out, and rotated horizontally before a fairly fine blowpipe flame, arranged so that the flame touches the glass between the paper strips. Presently the bottle may crack round the heated circle, but, if not, it should be dipped into the water once more, vertically (this is important), when the crack will usually occur evenly, and the lower half will fall into the water. The sharp edges

should then be ground on emery-paper, moistened with camphorated turpentine.

Broken reagent bottles, stock bottles, measuring cylinders, gas jars and many other articles may have their usefulness renewed by treatment such as this. Measuring cylinders, so cut down, should have the tops bordered, not ground, by holding in a large blowpipe flame, and rotating carefully until the edges soften. A piece of conical carbon is then used to widen out the opening, and, while still hot, one portion about $\frac{3}{4}''$ wide is more strongly heated and a lip is bent outwards by means of one edge of the carbon, or the triangular copper piece shown on p. 84.

Cutting Glass Tubes.—A second method for the cutting of measuring and similar jars, but which answers best with thinner glass vessels, such as beakers, test tubes, and ordinary glass tubing of all diameters, consists in leading a crack round the glass. The difficulty is in starting a crack successfully. A file cut is made at the desired place, and extended to a length of about $\frac{1}{2}''$. The middle of this is then touched with the red-hot point of a glass rod, not more than $\frac{1}{16}''$ in diameter. The hot glass should not be in contact more than one second, and a crack will usually start from that point along the file mark in both directions. This crack may now be led in any direction, indeed specially shaped vessels may be cut out fairly easily. For instance, a model bucket or tub, Fig. 61, has more than once been cut from a beaker in this way, no difficulty being experienced in leading the crack round the lugs, provided too great a distance was not attempted each time. To lead the crack along, the same hot glass rod is used as before, but it should not touch the glass, though approaching as nearly as possible to it immediately in front of the crack. The crack will then continue *as far as the hot rod*, where it will again stop. In this way the crack may be led completely round the cylinder, or in whatever direction it may be desired.

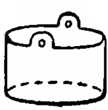


FIG. 61.

In cutting glass tubing of diameter larger than $\frac{3}{8}''$, this method of touching a file cut with the point of a hot glass

rod should always be followed—in the end it will be found much more satisfactory, and a saving of energy. Should it ever be necessary to cut a wide glass tube from a file mark only, the tube should always be wrapped in a duster, as wide tubes crack from a file cut in various directions, and severe wounds are sometimes caused in consequence. Jena glass tube should be cut by the paper strip and blowpipe method *without exception*, the glass being too strong to cut from a file mark by breaking, and too refractory to crack upon the touch of a hot rod. Care should be used in grinding Jena tubing, owing to its tendency to shatter, and whenever the grinding can be replaced by rounding and bordering in the flame, this method should be adopted.

In cutting narrow glass tubing and rod, a file mark is made (one cut forwards should be enough), with a file moistened with camphorated turpentine. The thumbs are placed opposite this mark, and the tube pulled rather than bent—a little of each, in reality. Usually the tube so treated breaks exactly at right angles, and gives an even edge. Only tubes less than $\frac{3}{8}''$ diameter should be cut in this way.

All glass tubes used for building up apparatus should have their ends bordered or rounded by the action of a blowpipe or Bunsen flame, but the tube should never be allowed to collapse, or even partially collapse, as this constricts the bore. Glass rods for stirring should be similarly rounded at the ends, but not allowed to become so hot as to collect into a piece of larger diameter than the rest of the rod. Stirring rod should usually be of small diameter, a $\frac{1}{16}''$ rod being none too narrow; it is better to break a rod than a beaker.

2. **Grinding Glass.**—Glass to be used for making up into cells, boxes, etc., should have its edges ground. This is done by moistening a sheet of emery-paper with a 10-per-cent. solution of camphor in fresh turpentine.[1] The effect of this

[1] Turpentine polymerizes somewhat easily, and the higher polymers are not suitable for this purpose, being somewhat sticky and inclined to solidify—hence the turpentine used should be freshly distilled, and have very little odour. The B.P. should not exceed 156° C.

liquid is that of preventing shattering or chipping of the glass, and though it is difficult to understand the reason, there is no question as to the fact, and, curiously enough, larger quantities of camphor and impure turpentine destroy the virtue of the liquid almost entirely. It should, therefore, be prepared in small quantities frequently, rather than in bulk, and the solution, as well as the turpentine, kept in the dark.

Having moistened the emery-paper with the solution, rub the glass along in the direction of its length—never across—backwards and forwards until the edge is smooth, though it presents a "ground" surface. By slightly inclining the glass the sharp edges may be removed.

All four edges should be so treated, and if required to be polished and transparent instead of ground, some brown paper should be spread upon a yellow pine or bass wood board, and flour emery sprinkled upon this, with a little camphor solution to moisten it, and the process repeated. The finest "matt" possible having been produced by this means, the edges are subsequently rendered transparent by a similar polishing or rubbing upon brown paper smeared with rouge and water, rouge and oil, or powdered rotten stone and oil. Microscope slips may be prepared in this way, several being treated at the same time.

When glass cells are being made, it is frequently of advantage to grind the edges of contiguous sheets at an angle of 45° in order to produce a mitred joint instead of a lapped joint (see Fig. 62). A mitred joint is much stronger than a lapped one, as a larger cemented surface joins the two sheets of glass, consequently a firmer hold is obtained, while, in addition, four mitred corners key each other into place, so that on holding the cell together, there is one position—the true square or rectangle —which the plates assume by preference, hence cementing is a much more easily performed operation.

The mitred corners are, however, more difficult to make, the grinding being rather tedious. The best method is to prepare a wooden block with an angle of 45° cut on one end. The plate is temporarily cemented with Chatterton's compound to the sloping surface of this block (see Fig. 63), with the edge

to be ground away slightly projecting below the bottom edge of the block. The lower surface of the block must be kept

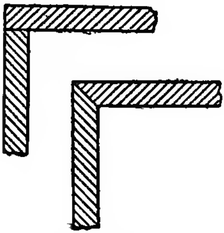


FIG. 62.

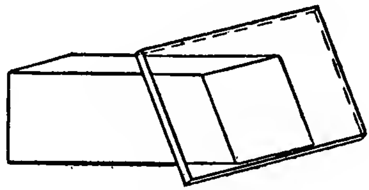


FIG. 63.

perfectly parallel to the emery cloth, during the grinding, which is accomplished by a circular motion. It is not necessary to do one sheet at a time, the whole four, if of equal size, may be ground at once by superimposing over the first plate.

Having been ground satisfactorily, the edges may be cemented together with any of the cements recommended in Section IV.—if only water is to be held, Chatterton's compound, "treacle glue," or "chromate glue," may be used. If only organic liquids are to be used, acetic acid cement is probably the best, though this latter requires fine grinding, and is seen at its best when cementing perfectly smooth or polished surfaces. When the edges have been smeared with cement they

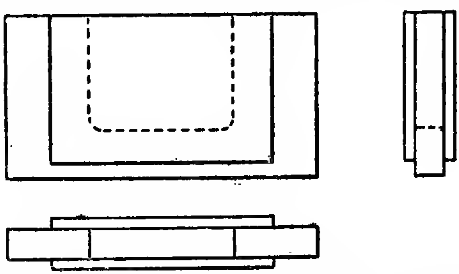


FIG. 64.—Lantern cell, made from sheet glass, the actual cell being ground by a wet emery wheel from a piece of plate glass.

are pressed together, and held in place by a few wrappings with string or fine wire until the cement has fully set.

Where possible, in addition to these cements, a strip of transparent linen binding (such as is sold for repairing music) may be applied to the outside of the joints.

Lantern cells, Figs. 64 and 65, spectrometer prism cells, Figs. 66 and 67, covers for specimens, and many other useful appliances are easily built up in this way, top and bottom being cemented on after the sides are made, by the same cement that is used for the edges, and the article completed before the binding wire or string is removed.

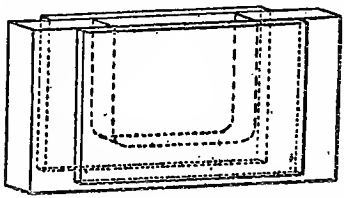


FIG. 65.—View of above.

The angle between the various surfaces may be varied as desired by the use of suitably inclined blocks, *e.g.* a 55° prism may be built up in this way, and subsequently based and covered as explained above.

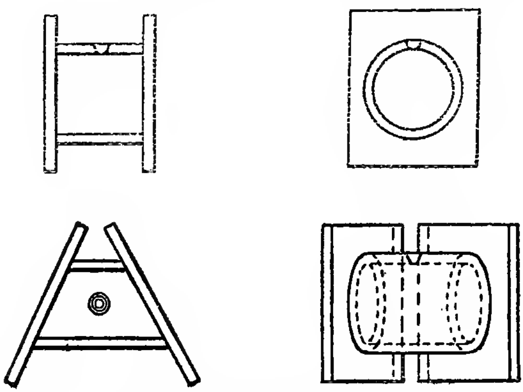


FIG. 66.—Polariscope, or spectrometer cells made from glass tubing and sheet glass.

3. **Drilling Glass.**—A prism to be used for benzene or carbon disulphide may, with advantage, be covered with a plate in which a hole has been drilled, and some little trouble is frequently experienced in drilling glass for such purposes. Two methods may be made use of—

1. Using a china drill.
2. Using a ground file.

In either case the cutting tool will be the same—the point of a rat-tail file, ground upon a wet grindstone to the shape of a triangular based pyramid.

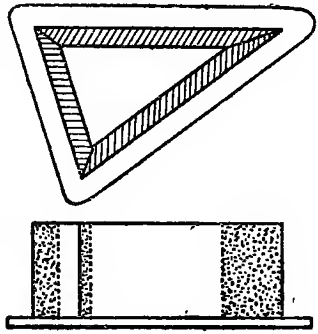


FIG. 67.—Hollow glass spectromete cell, built up of plate glass.

Such a cutting tool may either be mounted in the chuck of a china drill, or be used without breaking off the file by bowing.

A china drill is run by the inertia imparted to a heavy wheel near the work, and mounted on a long spindle, carrying the chuck at the wheel end, and connected with a sliding cross-bar of wood by means of a leather thong (see Fig. 68). Upon the downward stroke sufficient energy is given to the wheel to enable it to wind up the leather thongs and raise the cross-bar. Many forms of this tool are known, and it is not necessary to describe the management of the tool further.

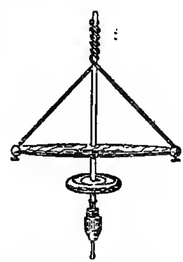


FIG. 68.—China drill.

Bowing is a simple method of communicating rotation to the file. The file is taken from its handle, and a small hole drilled part of the way through a brass blank in order to permit the revolution of the tang of the file. A string is now wrapped round the file, and attached to a bow at each end, so that when the bow is moved backwards and forwards, the file rotates (see Fig. 69).

The cutting tool is entered by dipping it in camphorated turpentine, and pressing firmly into the glass at the required spot, twisting half round while pressing. A small piece of glass is thus cut out, which allows the point of the tool to find entrance.

Moderate pressure only should be used, and wherever possible, the glass should be drilled halfway through from opposite sides, as fracture frequently occurs through the sudden puncture of the second surface, when the drill is apt to press too suddenly upon the sides of the conical hole it is drilling, and so fracture the glass.

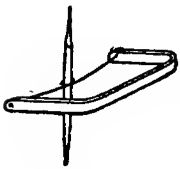


FIG. 69.

The drill must be kept moistened with camphorated turpentine, and must be inspected from time to time, and ground up to sharp edges when necessary upon a fine wet grindstone, or an oilstone.

Holes through glass tubing may be drilled similarly; in fact, spectrometer cells are sometimes made from glass tubing about 1″ diameter, this being ground to the required angle, and two pieces of patent plate cemented in position, a hole drilled in the top of the tube providing the necessary expansion and filling orifice, see Fig. 66.

"China drills," in the hands of the beginner, appear to be a little heavy, and frequently the glass breaks. The drills should be held as lightly as is consistent with cutting, and with practice it will be found that the drilling of glass is very little more difficult than that of china. In some cases, however, a file sharpened as directed, and twisted between the fingers and thumb, will work its way through the glass quite easily, and be under control to a greater extent than the drill could be, very little pressure being required, and the risk of breaking being therefore much smaller.

Small cells may be made by taking a piece of plate glass, and grinding it out by means of an emery wheel, moistened with camphorated turpentine, and cementing on each face a piece of patent plate, or even, for rough work, sheet glass such as is used in photographic plates, or microscope slips, see Fig. 64.

In this case the cement should be the acetic acid-gelatine one.

Plate glass may be filed into shape for a cell, but it is rather laborious. The file should be constantly moistened

with camphorated turpentine. A badly fitting burette stopper or the stopper of a reagent or other bottle may be ground to a good fit by moistening with a thin paste of flour emery, and camphorated turpentine by inserting the stopper with a twisting motion and working backwards and forwards. It should be frequently removed, and reinserted at a different place, and this process should be continued, plenty of the emery-camphor-turpentine mixture being used until the cleaned stopper fits accurately without rocking. The ground surfaces must be well washed before use. Burette stoppers should be greased with special grease, as recommended in Section IV.

SUB-SECTION (B)

BENDING AND BLOWING

I. Material

The glass used in glass blowing is either "lead glass" or "soft, soda-glass." Magnesia or other glass is too hard to work comfortably in an ordinary flame, and such work as may have to be done upon it demands the use of the oxy-gas flame, which will be treated of later. Ordinary "hard" or "combustion" glass may be worked, though with difficulty, in an ordinary blowpipe flame, but it would be a misnomer to call such working "blowing." Hence we are driven to deal only with soda-glass work, in this section, lead glass being very little used nowadays.

The glass is made in practically all the usual sizes and weights, consequently no difficulty will be experienced in obtaining suitable material, though in ordering, it is well to state specifically that the glass is for glass blowing. It may be obtained from almost any dealer in scientific apparatus, but, as it shows some tendency to perish or devitrify after some time, it is well to secure a stock from some tradesman whose stock is constantly moving. Messrs. Müller Orme & Co., 148, High Holborn, may be relied upon in this way.

Soda-glass is easily recognized when under treatment in the blowpipe flame, but is not so easy to recognize while in stock. Usually, however, its colour, looking at a tube endways,

will be pale green to dark green, not to be confounded with the distinct opalescent blue of Jena tube or the hard "white"[1] of combustion or ordinary hard glass. At the same time some very good soda-glass has a distinctly pink colour, and again, short pieces show practically no colour, so that little satisfaction is to be gained in judging by colour alone.

Owing to its lower melting point, however, soft glass has a more perfectly transparent appearance, and a smoother surface than hard glass, and is usually quite free from the longitudinal streaky appearance found in the harder glasses. Occasionally one sees a piece of soft soda glass with a streak down it, but such a piece should be rejected. The streaks in soda-glass are mostly due to air bubbles, and these will be found very inconvenient during the working.

While in the flame, soda-glass gives its characteristic yellow colour almost at once; hard glass does not show this yellow colour for some time, though, as sodium is present in most glass, it may always be expected to show more or less yellow in the flame.

In addition to indicating the presence of sodium almost instantly in this way, soda-glass melts with great ease, and shows a peculiar greenish translucent tint when ready for blowing. By this it is most easily recognized, though it is almost impossible to describe the appearance.

The ease with which soda-glass melts in the blowpipe flame will be the cause of some little trouble to the beginner, who usually collects too much melted glass for his purpose. Afterwards he frequently collects too little.

II. Tools required in Glass Blowing

The Blowpipe.—No article of equipment is more important than the blowpipe used in glass working, and no article is more difficult to obtain. It is quite the exception to enter a strange laboratory and find in it a blowpipe suitable for glass working. Blowpipes of the old-fashioned "Herapath" type are quite useless, as are, more or less, most of the "fancy"

[1] "White" is a trade name—it should be, of course, colourless.

types that are supposed to do so many things; indeed, most tools that combine various kinds of usefulness do so at the expense of each. At the same time the professional glass-blower's blowpipe is somewhat of a snare and delusion to the beginner, for whose benefit this is written. Later, when the student has acquired a thorough experimental knowledge of his material, he will find many advantages in the double flame, but the author's experience is that an ordinary blowpipe such as that described below will be the most satisfactory one with which to commence work.

A blowpipe should have the following characteristics—

1. It should stand upon a firm base.
2. It should be capable of being tilted at any angle.
3. It should be under control from one hand only.
4. It should be capable of giving a flame 4″ or 5″ long, tapering gradually from $\frac{1}{8}$″ wide at the blowpipe to a fine point, yet with a single sudden movement give the brush flame upwards of 10″ long, and spreading towards the end instead of tapering.
5. It should be free from the white flame-tip at the jet.

Several such tools are upon the market, perhaps the most successful one being that known as "Letcher's Triple jet" blowpipe at 25*s.* (Fig. 70). One equally good, save that the stand is unnecessarily high, is Messrs. Fletcher, Russell & Co.'s "C 10" at 12*s.* 6*d.* The latter tool would be almost preferable to the former, if, instead of having the flame some 10″ or 12″ above the bench, it were cut down to half this height; an exercise quite easily performed by any one who has worked through Section II.[1]

Fig. 70.—Letcher's triple-jet blowpipe.

Letcher's blowpipe has three differently sized jets at angles

[1] Since writing the above, Messrs. Fletcher, Russell & Co. have placed upon the market a new blowpipe, C 10 B, modified in accordance with the author's suggestion, and capable of giving a flame in any direction. See Fig. 71.

of 120° apart, mounted upon a ground conical pillar, which may be tilted through a quadrant and clamped by a milled screw. There is also a bye-pass which enables the jets to be changed instantly by swinging round without the extinction of the flame. By this means all the above-mentioned flames are available. No better tool could be desired, though the bye-pass might be a little stronger mechanically.

Messrs. Fletcher, Russell & Co.'s blowpipe, after being cut down, will be found an exceptionally handy tool, as one tap controls both gas and air, and ensures a perfect proportion of

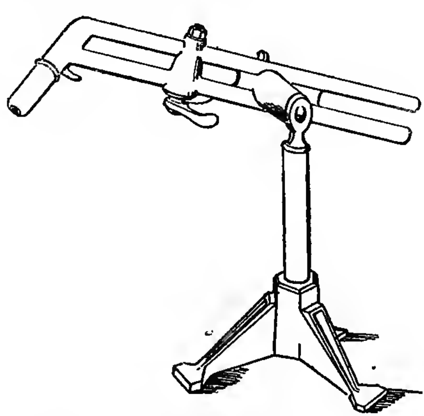


FIG. 71.—Fletcher, Russell & Co.'s new pattern C 10 B blowpipe.

gas and air at all jet apertures. The actual jet is constant for all flames, and an advancing sleeve over the outer tube enables one to get rid of the white tip for various flames. The actual working of this for small jets is more easy than that of Letcher's machine, as the flame comes gradually and with great precision to the size required, while in Letcher's, the small flame is only obtained by moving the jet round beyond the correct central position, as though there were too large an air supply.

The actual regulation of the gas and air supply requires to be made for each kind of gas used; a blowpipe correctly adjusted in one town does not necessarily work well in another, owing to the difference in the composition of the gas.

Taking out the plug, small grooves will be found to have been filed in order to supply the smaller flames, and these may either be closed with solder or opened with a file, according to the change desired.

A blowpipe should be so adjusted that the gas just remains lighted when the tap is quite closed, the air being then completely shut off.

The double jet of the professional glass worker is obtained by opposing two ordinary gas blowpipe jets, arranging these so that they just flatten against each other. They are blown through a **T** piece from a single bellows, in order that the

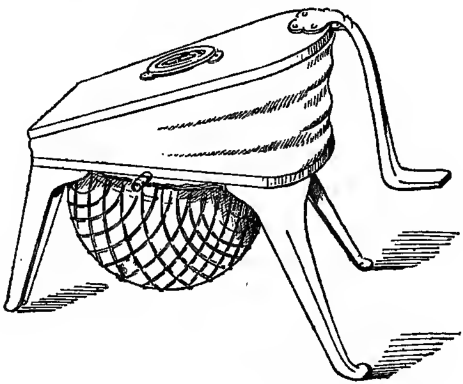


FIG. 72.—Fletcher, Russell & Co.'s No. 5 blower.

flames may be exactly similar. The use of this device at first is not recommended, as there is great difficulty in obtaining exactly the desired temperature, and the flame reduces the glass to a workable condition too quickly for a beginner. It may with advantage be used later, but for much of our work it is an advantage to be able to vary the temperature and the area of glass under treatment by simply moving the glass away from the flame, and this is difficult to secure in the case of a double jet.

Blower.—There appears to be no better blower on the market than Messrs. Fletcher, Russell & Co.'s No. 5 (Fig. 72), which costs about 25*s*. Fans, bellows, compressed air, Körting

pumps have all been tried, but there is no satisfaction in any device that gives a continuous stream of air at constant pressure. The use of an indiarubber chamber stored with air at a foot-controlled pressure really adds a third hand to the glass blower, who controls his flame through the air pressure, and this with the foot. With any continuous supply a tap is necessary in order to alter the pressure, and unless this is worked with the knee, or some similar contrivance arranged, the operator must release one hand from his work. In our work, where the

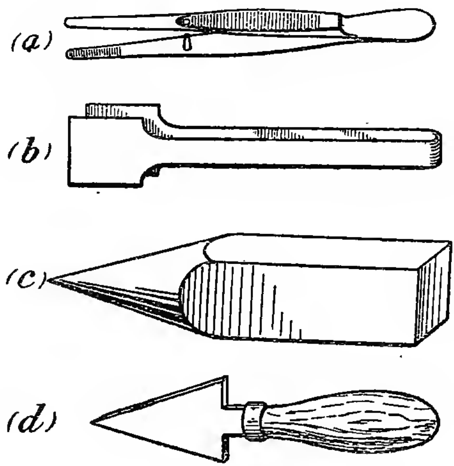


FIG. 73.—Glass-working tools.

maximum amount of variation is required, and no two "jobs" are alike, control and variation is of the utmost importance, and experience shows that two blowpipes cannot be driven satisfactorily from the same bellows, nor from a continuous supply of air, unless the work to be done is continuously alike.

Tongs, etc.—A pair of flat tongs such as shown in the sketch should be available; a triangular piece of copper $\frac{1}{16}''$ thick in a handle, for opening tubes, etc., or a block of compressed charcoal shaped to a conical point, and a pair of fine-pointed forceps will be found useful. See Fig. 73.

These may all be made for a few pence by a student of Section II. A steel or iron wire, about $\frac{1}{4}''$ diameter, and tapering to a point (Fig. 74) is also very useful for widening out a flange on the side of a tube, but tools of this kind may be made as required for special purposes, and, in the main, their aid will be required but seldom.

FIG. 74.

In addition to the blowpipe, a fish-tail burner on stand should be available, and all bending may then be performed on the bench. This should be arranged so that it is not necessary to disconnect the blowpipe in order to accommodate the ordinary burner.

Special blowpipe tables are frequently listed and sold by makers of apparatus. It is, of course, an advantage to have a separate blowpipe table, but a specially made one is not necessary. Any ordinary table covered with asbestos millboard and arranged at a convenient height will serve the purpose. Whether one sits or stands while at work is a matter of personal choice. It would seem that greater control over the bellows, and hence over the flame, may be exercised while standing, but most professional glass-blowers consistently sit, whatever the size of their work may be.

Students should bear in mind that it is simply an accurate knowledge of the material that enables a glass-blower to produce his effects with such ease, and that at the commencement of their endeavours, therefore, they will find considerable difficulty in obtaining eyeable results—indeed, will be inclined to accept an inferior piece of work as the best they can do, and pass on to the next exercise. If, however, they repeat the exercise, a much better result will in almost every case be obtained, inasmuch as they will start with less ignorance than before. One or two hours' work at glass-blowing will show no progress worthy the recording, but a course of systematic endeavour, extending over some forty or fifty hours, will invariably be sufficient to free a student from any fear of the material. After spending that time at the work most students are able to undertake the making of filter pumps, condenser

jackets, eudiometers, voltameters, and similar pieces of apparatus. Personal instruction is, of course, much to be preferred to descriptive text-book instruction, but such details will be found in the subsequent pages as will enable a student to progress as far as that stage at which he experiments upon method for himself, and when this stage is reached, further instruction is unnecessary.

It cannot be too strongly impressed upon a beginner that for a time he will be thoroughly dissatisfied with his results, and that nothing but constant repetition will enable him eventually to master the nature of his material so as to produce whatever he desires. Once this point is attained, however, his progress will amaze him.

Curiously enough, one's skill appears to vary from day to day. On some days one may dare all things successfully, while on others each attempt at even a simple exercise ends in failure. In the latter case, rest is the only cure. On the other hand, skill once acquired appears to lie dormant during comparatively long periods without sensible loss, though, of course, no progress will so be made.

The actual physical skill necessary in glass-blowing is small, the muscular training necessary to secure a perfectly steady hand and arm, and to enable one to revolve a tube steadily and regularly without altering the position and direction of its axis, being almost the summation of the physical requirements. The ability to blow and work glass successfully is acquired in consequence of—

1. A knowledge of every trick and possibility of the blowpipe, and of how to secure any desired condition instantly.

2. A knowledge of what the material can and cannot do, and of the outward signs by which its suitability for various treatment may be recognized.

3. A spirit of daring, to take instant advantage of a condition immediately it is recognized.

Some forethought is also necessary, to have handy all pieces of apparatus, tools, etc., and to arrange so that a hot piece of glass need never be put down while a subsidiary piece is being made.

It will be noticed that these are mental rather than physical attributes, consequently a glass-blower will become successful when these have been so thoroughly absorbed and incorporated into his personality as to become subconscious.

III. Exercises in Glass Bending.

For this purpose a "batswing" burner should be used, though it should never be turned full on save under very exceptional circumstances. The flame consists of two parts—a cool "blue" or transparent centre portion, and a hot luminous fringe. This latter is the part to be used.

Exercise 1.—Take a piece of 4-mm. bore tube, about 15 cms. long, hold it lightly between the thumb and forefinger of the right hand, in the upper portion of a flame such as that shown in Fig. 75 (2); holding with the left hand is not necessary, though it may be used as a guide. Turn the tube slowly and regularly upon its axis, taking care to give a complete revolution before turning back. The revolution may be at the rate of once in about four seconds. A higher speed is more difficult to control, and has no advantage in increased evenness of heating. If the tube is being correctly held, it will be covered with an even film of carbon at the end of the first complete revolution. Should it be otherwise, the position must be altered till the carbon deposits evenly over the whole of the surface to be heated. There is a tendency to hold the tube too low in the flame, and this will be shown at once by an uncovered space upon the tube.

Fig. 75.—Batswing flame: (1) turned on full; (2) turned down for glass bending.

Proceed with this slow rotation until the unsupported end of the tube shows a tendency to fall; then cease rotating the tube, and simply invert it, allowing the tube to straighten itself out. Then remove from the flame immediately, and allow the end to bend down at its own rate until the desired angle has been reached, when the tube may be held by both hands in that position, until sufficiently cool to be put down without risk of further

bending; three or four seconds will usually suffice. Should the tube not go over quite to the desired angle, it may be assisted by a very gentle pressure, but this must be done with caution, and before the tube has become hard again. All bending should be done out of the flame, and at one operation. Reheating is troublesome, and usually the second bending follows a different plane from the first, spoiling the appearance of the bend.

The test of a bend is that no sharp angle appears, and that the diameter is the same throughout the whole bend, in every direction, *i.e.* that the tube does not become elliptical in section at the bend, see Fig. 76 (2).

A Bunsen burner cannot satisfactorily be used for bending, as

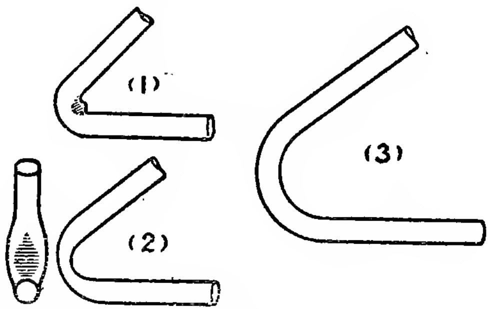


FIG. 76.—Sharply bent tubes: (1) produced with too small a flame; (2) bent when insufficiently heated; (3) correctly bent.

the flame is hollow, and too narrow, but one fitted with a Ramsay head is suitable for long bends.

EXERCISE 2.—Having bent a 15-cm. tube at right angles, bend similar pieces at 30° and 60°, noting the increasing tendency to kink at the angle as this becomes smaller. This tendency may be minimized by pulling or rather pressing the two portions of the tube apart when past the right angle, so producing a more curved corner.

EXERCISE 3.—It is more difficult to bend a piece of glass tubing exactly at a predetermined spot than to take a larger piece of tube, bend it, and cut out the required piece. Exercises will follow, however, where this second method will not be possible, and it is well therefore to practise bending a tube, say 5 cm. from one end, or to allow a straight piece 5 cm. long to remain after bending. This will, of course, be attained by using as small a flame as will

just perform the work desired, and by holding the tube in the flame in such a way that the centre of the ultimate bend is in the centre of the gas flame. The curve taken by a tube in bending will be exactly that which can be made out of the heated portion, consequently one generally knows beforehand the kind of curve which will result.

EXERCISE 4.—From a 20-cm. length of tubing make a U-tube, having similar curves at the base, and limbs of equal length (two right-angle bends, Fig. 77).

EXERCISE 5.—Bend a 20-cm. length of tubing twice, at right angles in opposite directions, keeping the whole in one plane (Fig. 78).

EXERCISE 6.—Bend a 20-cm. length of tubing in the form of

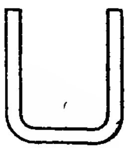


FIG. 77.

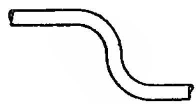


FIG. 78.

a U at one heating. The tube must be heated in the middle for about 7 or 8 cm., and smartly bent, keeping the two limbs well pressed apart while finally cooling.

EXERCISE 7.—Make a "Clowes" boiling point tube. This is done by first bending in opposite directions as shown in Fig. 79.

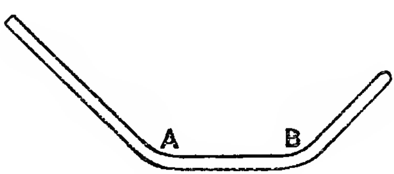


FIG. 79.

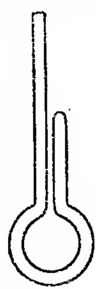


FIG. 80.

Then cooling, and heating the portion A B until rather softer than usual, and quickly turning the ends backward until the desired shape is reached (Fig. 80). It is essential that the previous bends be

perfectly cold before reheating for the final bend, otherwise the residual heat in each bend (different in each case) will be added at these points to that given to the straight portion of the tube, with the consequence that the old bends will soften first, and all the subsequent bending will take place there instead of along the tube.

The closing of the end of the tube is dealt with in following pages.

Spirals are made by winding hot glass tube round a cylinder of carbon, or, if small, by direct bending. A hollow and collapsible cylinder of copper may be substituted for the carbon cylinder, the method of working being as follows :—

A sheet of copper is cut, the length of the finished spiral and three times its internal diameter. This is bent into a cylinder round a mandrel of wood, mounted in its turn by means of two nails driven axially into the wood and fitting into two V-shaped grooves cut in two upright wooden supports. A length of glass tubing is placed above this cylinder, and at the suitable angle, the

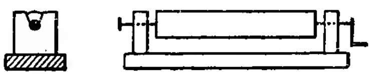


FIG. 81.

blowpipe flame is allowed to play upon the tube until it bends round the cylinder, to which it is then wired with copper wire. The blowpipe is then used to soften the next piece of glass, and the cylinder gently rotated as the glass softens, winding the tubing round it into a spiral. When completed, the whole is lifted from the support, and the mandrel withdrawn. The copper sheet may be made of smaller diameter by overlapping its edges and likewise withdrawn. See Fig. 81.

Students able to perform these preliminary exercises may proceed to Part IV.

IV. Exercises in Glass Blowing.

Preliminary Notes.

The blowpipe flame will require some little investigation before the commencement of actual work, and students should make themselves thoroughly familiar with the various flames and the quickest methods of obtaining them.

As a rule, students use the blower much too freely, and pass far too much air through the flame, cooling it unduly, and preventing the formation of a well-shaped flame. The blower should be worked with gentle and gradual strokes, rather than in rapid puffs, and the flame produced should have a pointed tip, and be practically silent. Opening the control cock will convert such a flame into a cooler, larger, and broader flame, suitable for warming a piece of glass to the required temperature for working, or cooling off (annealing) a piece already worked—this without any difference in the pressure upon the air sent through the flame. Closing the control cock, conversely, will produce a fine pointed flame, very hot, and suitable for heating one special spot in a tube without unduly heating the surrounding glass. Thus all flames required can be obtained by the use of a gentle current of air.

It may be noted here also that it is necessary for students to acquire the ability to work the blower quite independently of any movement of the hand; and the not unusual picture of foot, arm and head moving in unison should never be seen after the first few hours' work at the blowpipe. In order to help in the attainment of this freedom of action, it is well to practise independent movement while away from the blowpipe. Take a pen-holder, for example, and holding it between the thumb and fingers of the right hand, roll it completely round on a horizontal axis, never varying its position in space; then, having acquired some dexterity in this occupation, continue the motion while adding the movement of the right foot such as would be made use of in manipulating the blower.

Dexterity in these particulars will be found of the utmost service in handling glass, and will well repay time spent away from the blowpipe in their acquirement. The flame of the blowpipe is fixed, and it is of the utmost importance that the glass-blower should be able to rotate his glass, and thus heat it evenly, while keeping it at one particular point in the flame. Should the glass leave the flame during any part of its rotation, one portion of it will be cooler than the rest, and will therefore not respond as readily to whatever subsequent treatment the glass is subjected, an uneven result being produced,

see Fig. 82. It may be taken for granted that most of the unevenness in glass work is due to unequal heating of the glass, consequently the importance of this point can hardly be overestimated.

Much importance is also to be attached to the size of flame used, and no hard and fast rule can be given here; experience is the best and practically the only guide. Too small a flame localizes the heat unnecessarily, while too large a flame gives an inconveniently large quantity of hot glass, which is apt to get beyond control. At the same time, expert glass workers can control larger quantities of hot glass than beginners can, so make use of larger flames, and produce their work much

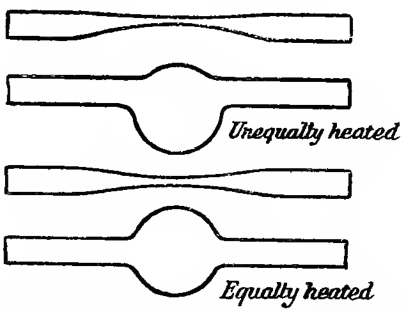


FIG. 82.—Showing effect of working glass when unequally heated, and when equally heated, through incomplete and complete rotation respectively.

more rapidly. As dexterity increases, larger flames may be used, but it is recommended that small flames be used at first. When removing hot glass from the flame for blowing, it should be remembered that if blown immediately, the thin portions will become thinner, but if allowed to cool for two or three seconds before blowing, the thin portions will have hardened, and therefore the thicker portions will become thinner. Control may therefore be exercised in this way.

All work in glass blowing should be done calmly and easily. A slow motion of the foot, gentle handling of the glass, quiet and easy movements of the various portions of apparatus under construction are the characteristics of expert

glass working. Any excitability or rashness, any attempt at extraordinary rapidity will almost inevitably lead to failure, though it is admittedly difficult for a beginner to restrain some excitement at the instant the heated glass reaches the correct condition for making an important joint.

When an exercise is completed, it is usual to cool the glass slowly. This is done by holding it in a flame of gradually decreasing temperature (*e.g.* the luminous blowpipe flame), and evenly distributing a coating of carbon over the worked portion of the glass, gradually withdrawing the work from the hot flame, and finally allowing it to stand for some time before removing the carbon with a soft duster. This gives the glass an opportunity of accommodating itself to any undue strains, and to this end the temperature should, at first, be as high and as fully and equally distributed over the worked portion as possible, which should be just short of softening, in fact. Gradual cooling will then, in most cases, prevent, or at least minimize, subsequent fracture. A second and excellent method, in case of complex glass work, is to wrap it up quickly in cotton wool, which, of course, burns near the hot glass, but this does not matter. This process of "annealing" is an important one, especially for the beginner, who by its aid may frequently save a piece of apparatus that would otherwise go to pieces on cooling; but it is noticed that the more expert a glass-blower becomes, the less he makes use of the annealing process. The reason appears to be that he equalizes all strains in the working up of the glass, taking care to keep all the glass at as high a temperature as possible until the work is completed, and also paying special attention to the securing of an equal thickness of material throughout. This latter point, indeed, is one which is somewhat overlooked. Glass work perfectly stable at high temperatures will crack on cooling, if different parts are of different thicknesses, and although careful annealing may preserve such a piece of work for the time being, in all probability it will snap under the slight difference of temperature resulting from handling, even though three months have elapsed since its manufacture. Such pieces of apparatus are treacherous, and are sources of considerable inconvenience to

a teacher preparing or delivering a lecture. In addition it should be remembered that soda-glass of good quality needs little annealing; that is, indeed, one of its essential properties; consequently there is much to be said in favour of the view that one should subject a piece of glass work to heavy strains immediately after making it, as it is better that it should crack then, than during a demonstration. Once a piece of work is completed, treat it carelessly—do not anneal; put it down and let it cool as it may: pull it in various directions, etc.; so that if it survive, its reliability is assured. A beginner will have considerable objections to such a procedure; it is not an uncommon thing to see a beginner surround himself with examples of glass working upon which he dare hardly breathe, and his distress is very marked when a friend destroys one piece after another in merely handling while examining it. Work such as this is fit only to be destroyed; it certainly is of no use in apparatus fitting, and would be a source of endless trouble and annoyance to any lecturer into whose hands it might pass. In addition, the maker has evidently not mastered the correct methods of work. It is painful to watch the intensity of expression on the face of a beginner when a "clumsy" teacher in handling breaks a piece of glass work at which the student has hardly dared to look since it was made, but the best test of the efficiency and correctness of the work is to subject it to a greater strain than it will ever have to bear in actual work. Glass work is not made simply for exhibition purposes.

This applies in the main to the smaller pieces of apparatus, such as T, Y, U-tubes, Würtz-flasks, etc.—there is, of course, a reasonable limit in all things, and one is justified in taking even special care of a Hoffmann's Voltameter or similar apparatus, which it would be folly not to anneal.

In the following exercises, students are recommended to commence work with 20-cm. lengths of 4-mm. bore tubing, and to increase the diameter of the tubing and the thinness of the walls as success rewards their efforts.

Tubing need not always be *cut*, it should usually be drawn out before the blowpipe, as this produces a closed end on each

piece, which is generally required in glass blowing. All such ends may be used up in making the various junctions to be described subsequently, and much glass will be saved by attention to this detail.

EXERCISE 1.—*To make a wash-bottle jet.*

Take a piece of 4-mm. bore tubing, hold between the thumb and finger-tips of the right hand, and rotate evenly in the hottest portion of the blowpipe flame, until signs of bending appear. Then lightly support with the left hand, until evenly heated, and removing from the flame, gently continue the rotation, but in addition pull the two ends apart slowly, increasing the pull as the glass cools, until the required shape is produced. Wash-bottle jets should not have too pointed a tip, as they are liable to break, and so bits of glass find their way into the beakers and precipitates during washing; nor

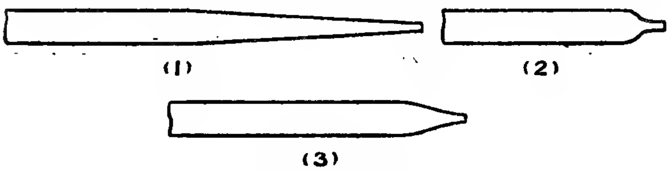


FIG. 83.

should they be too short, or their shape will prevent an even stream being ejected.

If pulled apart too soon, No. 1, Fig. 83, will result, thin walled, weak, and very pointed. If allowed to cool too much before pulling, No. 2 will be produced, from which an even stream will never be ejected. The aim should be in the direction of producing one like No. 3, stout walled, not too stunted, and not pointed enough to risk breakage.

The jet when made should have both ends heated in the flame until the sharp cut edges fuse, and the ends become rounded, so that they do not cut the rubber tubing forming the junction to the bottle. The jet must be carefully rounded, as the diameter of the orifice will be determined by the amount of heating, and may therefore be arranged to give any desired size of stream. It should be noted here that a common error in jet-making is to suppose that any size of stream may be produced by closing up the tip of the jet, see Fig. 84 (*c*). While this is to some extent true, it is only so within fairly prescribed limits, as an uneven and jerky stream issues

from a jet such as that figured, owing to disturbing eddy currents being produced behind the projecting portions. A properly constructed jet should require little or no adjustment of the orifice after making, the contracted portion leading by a single and even curve to the correct-sized orifice. This is easily attained by allowing the tube to thicken in the flame before pulling out, Fig. 84 (*a*), and by

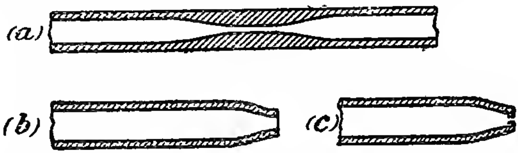


FIG. 84.—Stages in making a wash-bottle jet. The jet shown in (*b*) is too wide, and to be closed must be treated so as to produce (*c*), which will not eject an even stream. If (*a*) be pulled out correctly, a jet shaped as Fig. 83 (3) will result, and will need no constricting of the orifice.

pulling very slowly at first, giving the glass time to partly solidify before finally shaping. A little experience will soon show the exact amount of latitude possible, and any desired shape and diameter of jet may then be produced at will.

EXERCISE 2.—*To close the end of a tube.*

(*a*) *Rounded.* Proceed as in Exercise 1, producing a jet. Heat with a finely pointed flame at the point A, Fig. 85, and pull off sharply the thinner portion, when the glass is well softened. Turn the glass to a more acute angle to the flame, and heat the end until the glass shows signs of collapse. Blow gently to prevent this, and by alternate blowing and heating, always continuing the rotation, shape the tube to the desired hemisphere, the walls being equally thick throughout, Fig. 85 (1).

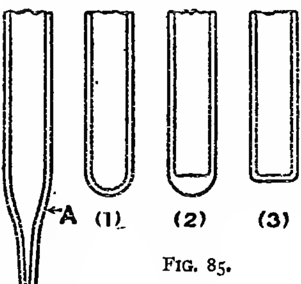


FIG. 85.

(*b*) *Flattened.* By heating the end of the tube so produced in the side of the flame, and maintaining the rotation, the glass may be permitted to collapse, leaving a flattened interior, while the hemispherical exterior is preserved,

Fig. 85 (2). This method is useful where quantitative results are desired from closed tubes.

Wide tubes cannot be treated in this way, the amount of glass at the tip being too great for equal cooling and contraction, consequently have first to be closed as in Fig. 85 (1); then reheated, and either pressed vertically downwards upon a block of charcoal, or "sucked" in, instead of being blown out, eventually producing an end like that shown in Fig. 85 (3). Several reheatings may be necessary in this case, the method adopted depending upon the diameter of the tube dealt with.

EXERCISE 3.—*To constrict the bore of a tube, while leaving the outside diameter unchanged.*

This is a very simple exercise in tubes of small diameter, but more difficult in larger cases, but as the practical application of this process is made mainly in tubes of small diameter, it will be sufficient to make use of tubes not greater than 10 mm. outside diameter.

The tube is heated as regularly as possible along about 2 cm. of its length where the constriction is desired, until the tube shows signs of softening, when the temperature of one portion of the heated part is raised, and the glass allowed to collapse slightly, this being aided by pushing in the ends of the tube a little. A further portion of the hot glass is then softened, and permitted to go through the same processes, until the length to be constricted is dealt with. The whole of this is then reheated just to softening temperature, and gently pulled out until the outside diameter of the constricted part is equal to that of the original tube. This must be done carefully, and if the tube shows any tendency to become too thin in places, the drawing out must instantly cease, and the thin part be built up again. The tube will thin out when that particular portion has been heated too strongly, and it is built up again by reheating, blowing a rough bulb with all the thin glass, and collapsing the bulb before a large flame, while pressing the ends of the tube together. Gradually the glass will return to its original diameter, but a bulge may be thus caused at the point last worked; if so, by pulling gently just as the glass is solidifying, the tube may be brought down to the desired diameter.

Another method of producing the constriction is to use a very small flame, and heat a small circle of the tube, rotating and gently compressing the tube meanwhile, passing on to the adjoining part when this small piece is completed.

Care must be taken throughout this, and other exercises, to rotate the tube gently and continuously, and to arrange that the rotation be of one complete revolution, neither more nor less.

EXERCISE 4.—*Joining two tubes end to end.*

In this exercise it will be well for a beginner to close the end of one of the tubes, either with a small cork, or a plugged india-rubber tube. The two pieces of tube are then held in a fairly large flame facing the blast (Fig. 86), in such manner as will secure equal heating for the extreme rim of each, and rotated slowly and evenly as before. When the respective rims are red hot, and begin to close in slightly, the two tubes are pressed together gently, and after adhesion is secured, pulled apart slightly, not sufficiently to narrow the tube, but to counteract any swelling at the junction that may have occurred when pressing the tubes together. At the instant immediately before solidification, the tube should be gently blown into, which will help to keep the junction of correct bore.

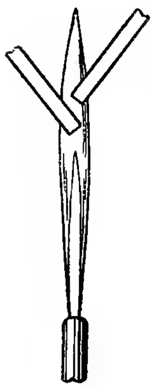


FIG. 86.

The first few attempts may not be very successful, from some of the following reasons :—

1. Too great hurry to place the hot rims together, resulting in a displacement of the axis of one piece relative to that of the other.
2. Too great delay in pulling apart after joining.
3. Too great delay in blowing.
4. Undue softening of the glass, causing a side collapse of the joint.
5. Unequal softening of the glass.

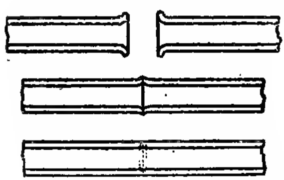


FIG. 87.—Stages in the joining of two tubes end to end.

In order to reduce the likelihood of these errors being made, the tubes may be separately heated, and when hot, expanded by a twist of the carbon cone (Fig. 87 (1)), afterwards proceeding exactly as indicated above. This, giving greater diameter to the tubes, reduces the prospect of error, but the joint so made is not likely to be so sightly as the first, owing to the greater amount of glass

accumulated at the joint. Moreover, if the pieces cool before joining, they frequently crack upon reheating.

The joint being made, and proving airtight, it may be necessary to improve its appearance, though when the skill has increased, the joint will be completed in a single operation. Should this be necessary, the whole of the tube at the junction may be heated, and as it softens, gently blown out into a bulb, while the parts are slightly pressed together. The thinner portions will blow out most, and this must be guarded against, many reheatings and blowings being necessary in order to coax the glass finally to an even thickness. It should be mentioned here, that reheating *partially* is of no use—the glass must attain the temperature at which it will flow, or coalesce. Finally, the bulb so blown is fined down, the tube being pulled out slightly at the same time as it is being blown into, in order to reduce the diameter to that of the original tube. Tubes joined in this manner should not show the joint at all (Fig. 87 (3)).

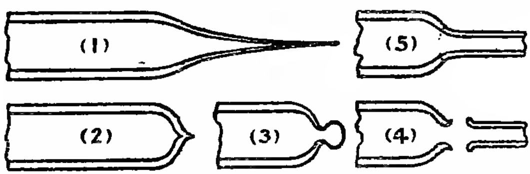


FIG. 88.—Stages in the joining of two tubes of unequal diameter end to end.

Two tubes of dissimilar diameters may be united similarly, by opening the smaller one slightly as above, and drawing the wide one down, cutting at a point where the diameter is slightly smaller than that of the opened tube, in order to allow for the widening of the aperture under the flame (Fig. 88 (4)). Reheating, blowing, and moulding may again be necessary, and any trace of thinning of the glass (indicated by a tendency to blow out more easily at one place than at another), should be at once eliminated by heating strongly about three times the area of the thin place, allowing it to collapse, and finally restoring its shape by blowing. In joining two tubes in this way, care should be taken not to pull the tubes apart, rather to keep them pressed towards each other, maintaining the correct shape by blowing into the tubes when necessary.

Tubes of different diameters have walls of different thickness, but, as explained in Exercise I, the wall of a drawn-out tube may be made of any desired thickness by suitable treatment. It is well, in joining tubes of unequal diameter, to arrange that the walls are of similar thickness at the point of junction.

EXERCISE 5.—*Blowing a bulb in the middle of a piece of tubing.*

For this purpose close up one end of a 20-cm. length of tubing; heat at the point where the bulb is desired, rotating gently, and holding the tube at the blowing end only, giving support to the other by permitting the drawn-out end to rest in the fork of the thumb and forefinger of the left hand. When the flame is coloured yellow, blow gently (still maintaining the rotation until cold), and return to the flame for the purpose of producing another similar bulb by the side of the first, the two bulbs being subsequently blown into one by means of a larger flame, pressing each portion of the tube inwards towards the bulb during the act of blowing (Fig. 89). By this means more glass is melted into the bulb, which is therefore

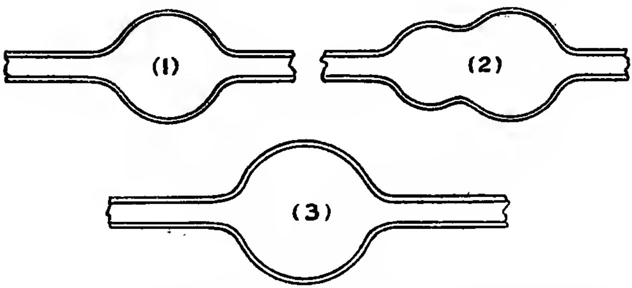


FIG. 89.—Stages in the blowing of a bulb in the centre of a length of tubing.

stronger than if blown at once, while, secondly, the pressing inwards produces a more spherical bulb.

Considerable practice will be necessary before a spherical bulb will be produced, and many reheatings may be required, but an apparent failure should not be immediately discarded; patience and continued endeavour will frequently produce the desired result from an apparently hopeless piece of work.

The bulb frequently appears on one side of the tube more than on the other, and this is due to uneven thickness of the glass, and consequent dissimilar softening caused by unequal heating. The remedy is to heat the smaller side of the bulb only, leaving the larger and thinner side untouched, to blow out the bulb until each side is of equal dimensions, then to reheat the whole, take down as far as possible, gently puffing air in from time to time in order to prevent total collapse (and consequent adhesion of glass across

the bulb), and finally to blow out while rotating the tubes, and pressing them together slightly.

Blowing and rotating simultaneously is arranged by wetting the tube so that it slips round in the lips, which should never *grip* the tube tightly.

Although many failures may be expected before success is finally attained, always and from the first a *strong* bulb should be produced. Weak and excessively thin bulbs denote failure to grasp the preceding method, and no subsequent exercise should be attempted until this fault is overcome. At the same time, it is not recommended that a student remain at this exercise until absolute certainty of obtaining a spherical bulb be attained. Practice at subsequent work will materially enhance his skill in dealing with hot glass, and consequently his prospect of success with this somewhat difficult exercise.

EXERCISE 6.—*To blow a bulb at the end of a tube.*

This exercise should be continued until absolute certainty is acquired. Subsequent exercises should not be attempted until this is the case, as upon its accurate and reliable performance many of them depend.

First close the tube as in Exercise 2, and produce the rounded

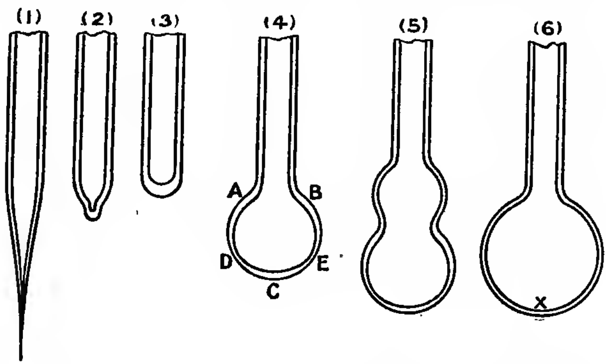


FIG. 90.—Stages in the blowing of a bulb at the end of a piece of tubing.

end shown there. Holding the tube horizontally, heat it for about 1 cm. at the end, transfer it horizontally to the mouth when fairly soft, and blow gently. The glass, on softening, will show a tendency to bend over, and this must be at once counteracted by a twist

through 180°, so that the hot glass falls back again. Similarly, even during the period of transference from flame to mouth, the glass may bend over, in which case it must be inverted before blowing, which must take place at the instant the hot portion comes into line, and at this same instant rotation may be resumed, in order to prevent any further falling out of line.

The tube is next heated for the second cm. of its length, and a second bulb blown on the top of the first in order to provide more glass, the two bulbs being subsequently fused into one before a somewhat larger flame, and blown into a single bulb as before. Blow strongly at first, and more gently as the bulb swells, in order not to reduce its thickness too much.

A 2-cm. diameter bulb is the smallest one should be satisfied with, and if a 20-cm. length of 4-mm. bore tubing were taken origin-

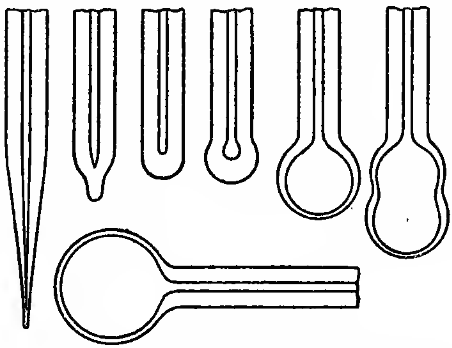


FIG. 91.—Stages in the construction of a thermometer bulb.

ally, the resulting bulb should be sufficiently strong to withstand the shock of dropping on the bench, bulb downwards, from a height of two feet. It should be a perfect sphere, the centre of which rests upon the produced axis of the tube, and it should have no extra thickness visible at X. Should this, however, be the case, it may be removed by heating this thickened portion with a fairly small flame, blowing out gently, and reheating and reblowing the whole bulb.

Success at this exercise is much more easily attained than at the previous one, and nothing short of perfection should be accepted—having attained which an attempt should be made using thermometer tubing (1-mm. bore). The only difficulty here is due to the liability of the glass to collapse and so close the bore. To avoid this, after closing by drawing off a small portion, heat the tube at the

point at which it resumes its full diameter, and pull off a second portion, if necessary, so producing a blunt end. Heating this for about 5 mm. up the stem, blow as soon as possible—better too soon than too late, and never permit the glass to accumulate at the heated end, nor the bore to collapse beyond the amount necessary to keep the small bulb concentric with the outside contour of the glass. Once the first bulb is correctly produced, no difficulty will be experienced in the completion of the exercise, which is carried out in exactly the same way as that indicated previously.

EXERCISE 7.—*To make a right-angled junction.*

Take a piece of 6–4-mm. tube, 20 cm. long, draw apart at 14 cms. from one end, and set aside to cool. When quite cool, heat the longer portion at one spot in its side without rotating or moving in any way, until it shows signs of collapse. A very fine flame should be used for this purpose. Blow down the tube, and expand it where it is softened; reheat until it collapses and expand a second time, the object being to build up on the side of the tube a cylindrical attachment, to which the incoming tube may be joined. This is a matter requiring some care. The tube should not be allowed to form into a thin bulb (or it will open out on the next reheating) until the junction is satisfactorily formed on the tube (Fig. 92 (5)). When this stage is reached, the top of this side tube is removed with a sharp puff of air or the stroke of a file, and the opening so produced, together with the rim of the incoming tube, is heated in the flame. Rotate the incoming tube, and take care that the contraction or recession of the heated glass of the longer tube takes place evenly, *i.e.* that the tube is evenly heated. When both are evenly and equally red hot, place the two portions carefully and slowly together, press together for *one second*, then pull apart while blowing down the open end of the tube. This will secure the equal thickness of glass at the junction necessary for a reliable joint, and the junction itself will be barely visible, as a circle round the smaller tube. Such joints should withstand any reasonable pulling upon any two parts—just as much, in fact, as one would give to a straight piece.

Frequently an airtight joint is made which is very unsightly. This should be reheated at the junction, first in the direction A, until a portion of each tube is softened and shows signs of collapse —a puff of air then restoring the shape. Several reheatings may be necessary, and it should not be left until an evenly curved joint is secured, though the whole junction must meanwhile be kept well

warmed—in fact, just short of softening. Having secured a good shape at A, proceed to deal similarly with B, the now cooler A keeping the joint firm meanwhile. Finally, treat the two sides similarly, and, if sufficient skill has been acquired, reheat the whole junction, blowing gently while it finally cools.

This method is a tedious one, and will in most cases be given up

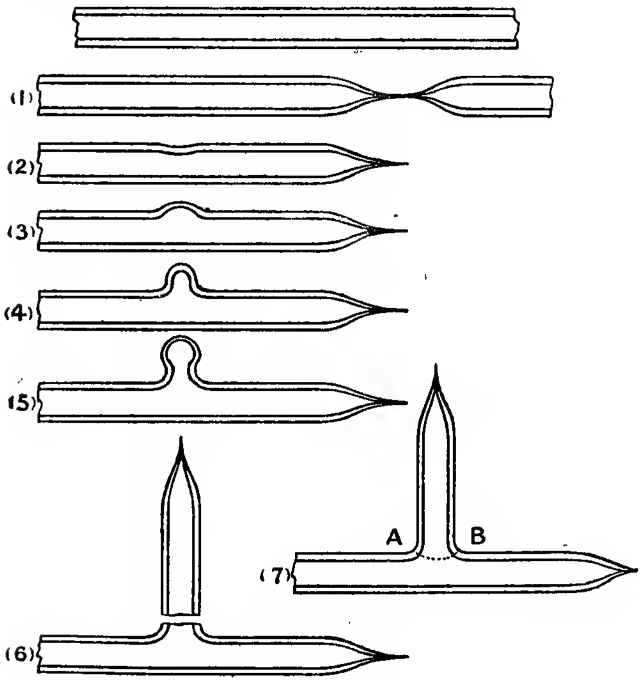


FIG. 92.—Stages in the construction o, a right-angled joint.

for the previous one, or rather the first one will be insensibly developed from the latter, which is somewhat in the nature of a patchwork job. Correctly performed, the first method produces a perfect T piece at the first operation.

EXERCISE 8.—*To make a* Y *piece.*

Bend a 14-cm. piece of glass tubing in the form of a V in an ordinary gas flame. When the tube is cold clean off the carbon

and proceed exactly as in the previous exercise, at the outer side of the angle of the V. Introduce the tail piece and finish off as before.

EXERCISE 9.—*To make an* X *piece.*

Proceed as in the T piece, Exercise 7, save that instead of working the cylindrical junction at right angles, it should be worked out at a more acute angle. Having sealed in one piece, commence the second a little further down on the opposite side, in order to give the two inserted pieces a common axis. The two junction points may be indicated before the insertion of either, but a better way is to insert one completely before commencing the second, in order to accommodate it better to the angle of the first (Fig. 93).

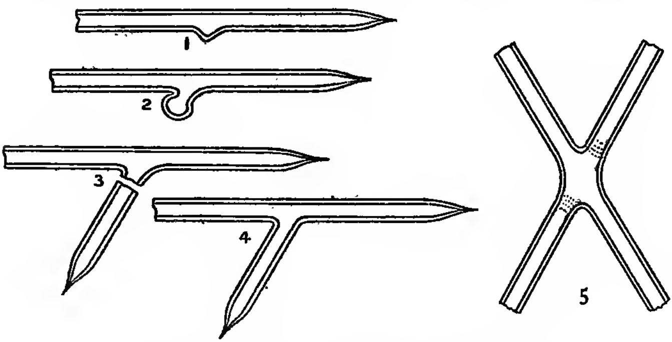


FIG. 93.—Stages in the construction of an oblique X-piece.

Before commencing the work all four tubes should be prepared, and cooled, so that they may be conveniently handled in any place or position.

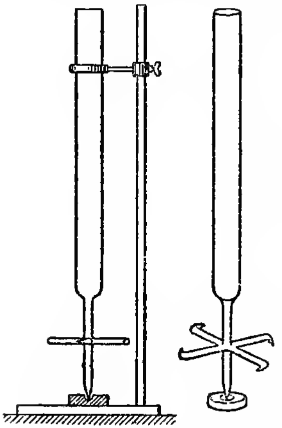
EXERCISE 10.—*To make a "Barker's mill."*

Make a T piece as in Exercise 7. Join a second limb opposite the first. Join in two tubes at the junction, opposite each other, in a straight line, but at right angles to the plane of the other four. Pull out the four arms, as in Exercise 1, to form jets, and while soft twist them each round in the same direction. See Fig. 94 (*b*).

Draw out one of the last inserted two tubes about 3 cm. from the junction, and close the tip into a strong point.

To the remaining upright tube, seal a piece of 3-cm. diameter tubing about 50 cm. long, and round, or "border," the upper edge

by heating the end in a large blowpipe flame, and, when it is softened, introducing a carbon cone, and gently pressing while rotating it against the softened edge. This gives a smooth edge to the end of the tube.



(*a*) (*b*)
FIG. 94.—Barker's mill.

The instrument is supported by a retort stand (see Fig. 94), a ring being placed round the upper portion of the upright tube, and a small piece of brass, having a V-shaped depression drilled in its centre, forming the base support.

As an alternative method the four side arms may be sealed into the wide upright tube, but much more risk of breakage is entailed by this method, owing to the difficulty of keeping every junction equally hot until the whole is completed—a difficulty not existent in the device described above, as the whole junction is more or less under the flame until completed. Provided the jets are small no disadvantage accrues from the narrow supply tube, as its sectional area is greater than the sum of the areas of the jets.

EXERCISE 11.—*Seal into a 6·4·mm. tube a piece of 1-mm. bore tubing, (a) at right angles, (b) obliquely.*

Little instruction will be needed for this exercise beyond the statement that, in each case, the thermometer tubing should be blown out, by successive heatings and blowings to the shape indicated in Fig. 95, being finally blown out from AB. This enables the tube to be treated exactly like one of ordinary bore.

EXERCISE 12.—*To make an "internal seal."*

This exercise is designed for the illustration of a process necessary in the construction of a filter pump. Take a piece of 15-mm. bore tubing, blow a bulb on the end, or close hemispherically, blowing out from this again a 5–7 mm. diameter spherical bulb, which is to be cut off, leaving only the flanges projecting. Close the wider end with a cork.

Prepare a second piece, say of 5-mm. bore, draw out to a point, blow a bulb of 10 mm. diameter at the commencement of the narrowing of the tube, and cut off the thin drawn out portion, as shown in Fig. 96 (2). Heat both in the blowpipe flame until almost softened, then introduce the jet and allow the bulb to rest upon the flanges of the wider tube. Heat this junction strongly,

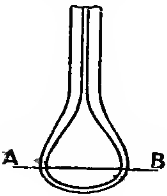


FIG. 95.

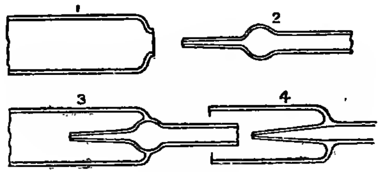


FIG. 96.

maintaining the rotation of the tubes as before, and when glowing, press together lightly, move to a vertical position, and blow into the tubes. This will make the jet return to the direction of the axis of the tube, and will finally seal the junction, while the extra internal air pressure will restore the shape of the work (Fig. 96 (4)).

A useful continuation of this exercise is to seal a jet through the side of a tube of similar dimensions to that given above.

EXERCISE 13.—*To make a filter pump.*

This exercise is a combination of several preceding ones.

A strong bulb 4 cm. diameter is blown at one end of a stout 8–6 mm. tube, about 30 cm. long, and a long jet is sealed into the bulb in line with the axis of the tube. See Fig. 97.

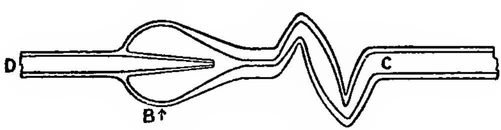


FIG. 97.—Filter pump.

A constriction is then made on the tube opposite the jet, and two or three acute bends made before the blowpipe, immediately below this constriction. These bends serve to break the jet of water, and so to make it carry away air in front of it.

The lower portion of the bulb is then heated, and the bulb

made of conical shape, until the jet centres immediately over the constriction.

Finally, a side piece is sealed in the bulb at B. The complete instrument is useful in either extracting air through B, or injecting air through C by means of a water jet passing down D.

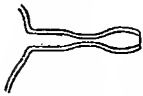


FIG. 98.

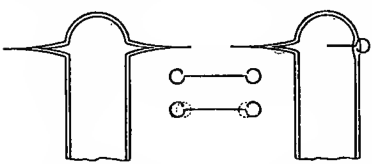
The tubes at D and B may be constricted slightly in order to allow stout rubber tubes to be fastened to them by binding wire, the most suitable shape being that shown in Fig. 98, which permits wetted tubing being slipped easily over a diameter it would not otherwise encircle.

All ends of glass tubes should be bordered or "rounded," to prevent damage to indiarubber junctions.

EXERCISE 14.—*To make a eudiometer.*

Take a 15–13 mm. tube, close one end hemispherically, and while still hot, heat a small portion of the tube more strongly, touch with a thin glass rod, and pull out the glass to a fine point (Fig. 99 (*a*)). Before breaking this open, repeat at a point immediately opposite.

Hold a piece of platinum wire about 2 cm. long in the centre, and bend each of the ends into a circle round a small glass rod. A piece of blue "enamel" glass rod is then drawn out, and wrapped round the wire in such a way as to enclose the end of the wire and a portion of the loop as indicated by the dotted line (Fig. 99). The enamel glass is heated very strongly, until it closes upon the wire like a "borax bead."



(*a*) (*b*)
FIG. 99.—Sealing wires into a eudiometer.

Cut the wire in the centre, removing in addition any excess of wire, in view of the distance it has to bridge. Cut off one of the drawn-out points from the long tube, insert one piece of wire, and, holding the tube horizontally, the wire hanging down through the hole, direct a fine flame upon the enamel until union with the glass takes place. Pass round the junction with such a flame, blowing into the tube as may be necessary in order to keep the correct shape.

Before cooling, when this is completed, insert the second wire similarly, heat the whole top of the tube thoroughly before allowing

to cool, which must take place slowly, and finally wrap the tube up in cotton-wool until perfectly cold.

Should the wires not be exactly opposite each other, at the finish, they may be brought into position by a touch with a hooked wire, but this should not be attempted until cooling is complete.

The enamel glass serves two purposes—

1. It fuses a little more readily than ordinary glass, and is therefore easier to work.

2. Its colour being distinctive, the progress of the junction is more easily followed.

The wires should be sealed into the tube in the shape indicated by the sketch A, Fig. 100. Purchased apparatus is frequently of the type B, which allows an inserted wire to pull open the loop of platinum wire, and strain the portion which enters the glass, causing it to break off after being used a few times. Both ends of the loop should therefore enter the glass, and this will be found to be the case if the instructions above are carefully followed.

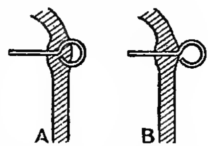


FIG. 100.—Sealing of eudiometer wires.

EXERCISE 15.—*To make a condenser jacket.*

Select a piece of 27–25 mm. glass tubing, cut off about 30 cms., with ends at right angles to the axis of the tube. Border these ends as before, and fit a cork to one end.

Prepare two side tubes, by blowing a bulb at the end of each, and, heating beyond A, Fig. 101, blow a second large and light one. When this is removed, we have an opened tube, with gradually thinning edges.

Commence by heating in a "cool" flame the whole of the glass where the side tube is to be inserted, rotating evenly until the whole cylinder of glass is hot at this place. With a small flame now heat strongly one point only, and gradually blow it out as in Exercise 7 for a T joint.

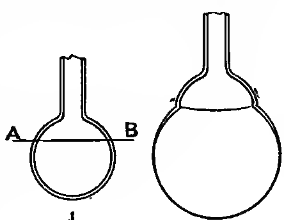


FIG. 101.

Insert a second cork into the jacket, and make the right-angled joint as in Exercise 7, wrapping in cotton-wool immediately the joint is completed. When this is quite cold, insert a second piece

in a similar manner, at the other end and on the opposite side to that already completed, wrapping in cotton-wool as before.

The whole difficulty in this exercise is to keep the glass from cracking, and this can only be accomplished by maintaining at the same temperature the whole circuit of glass while the joining is proceeding, and after the junction is successfully made, heating the whole to an even temperature, and then annealing in cotton-wool and cooling very slowly.

EXERCISE 16.—*To make an ozone tube.*

Select a piece of 27–25 mm. tubing about 30 cm. long, and one about 20–18 mm. about 25 cm. long. Seal a side piece into the

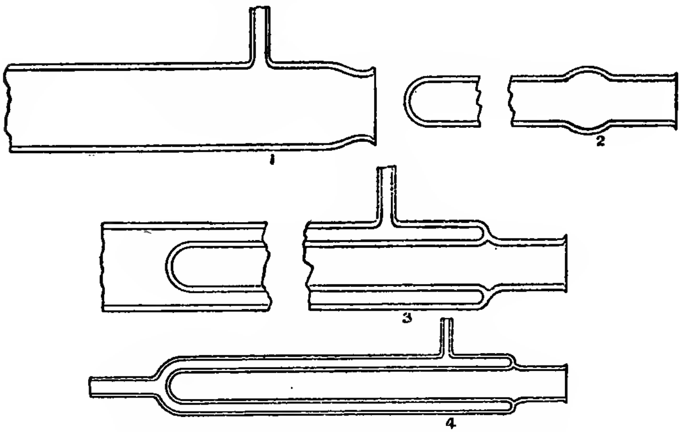


FIG. 102.—Stages in the construction of an ozone tube.

former about 7 cm. from one end, and slightly contract this end by drawing out, and blowing a thin bulb which is to be subsequently removed.

Draw out one end of the smaller tube, and seal up the end in the shape of a hemisphere; also blow a slight bulb near the open end, which will just prevent the small tube passing the constriction of the wider one (Fig. 102 (2)).

Wrap a strip of paper round the narrow tube and push it into its place in the wider one, sealing the joint in the usual way, as in Exercise 12, by heating both during rotation until softened, pressing together and blowing in successively at each open end until the final shape is that shown in Fig. 102 (3).

The supporting strip of paper is now removed, and the open end may be drawn out by softening about 3 cm. past the end of the inner tube, and drawing out in the usual way after thickening. Instead of sealing off, however, a straight piece of thin tubing should be joined in at this end in order to complete the apparatus. Finally, border all sharp edges (Fig. 102 (4)).

Corks may be used to close up any unnecessary openings during blowing, and if the inner tubes be too wide to blow into comfortably, they may be closed with a cork through which passes a narrow tube. Immediately they are completed joints should be wrapped in cotton-wool, which may be held in place by a few strands of cotton while the work is being completed. As far as possible a joint should be heated thoroughly all round after it has been successfully made, as this will tend to equalize all strains from the unequally heated patches, and lessen the liability to cracking.

EXERCISE 17.—*To make a Hoffmann's voltameter.*

Several types of this instrument are in vogue, the simplest in construction being described below.

Select a straight length of 15–13 mm. glass tube, and cut off two 50-cm. lengths, and two 10-cm. lengths. Also a 40-cm. length of 26–24 mm. glass tube.

Join the two 10-cm. pieces at right angles, as described in Exercise 7. Attach the wider 40-cm. tube to the side piece in the T, as in Exercise 4. Join the two 50-cm. pieces to the ends of the 10-cm. cross piece about 5 cm. from the ends (see Fig. 103). This latter portion of the work will present the only difficulty, which may be considerably lessened by mounting the glass upon a board, and binding round with copper wire, or by holding the various portions securely by means of retort stands and clamps, closing all openings but one, into which a cork carrying a tube is fitted, and the tube connected with rubber tubing to a mouthpiece for blowing. In this case the blowpipe should be removed

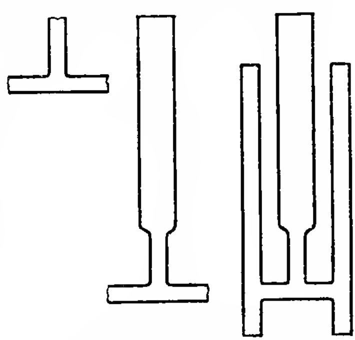


FIG. 103.—Stages in the construction of Hoffmann's voltameter.

from its stand and used as a hand blowpipe. Some little dexterity is required, but this comes with practice.

Finally, bought taps may be sealed on to the upper ends of the side pieces, or use made of broken burette taps, for the same purpose. As an alternative, the ends might be drawn out, and indiarubber connections closed by spring clips be affixed, suitable jets being inserted beyond the clips.

For the bottom ends, it will only be necessary to shrink a glass tube upon a platinum wire welded to a 25 × 5 mm. piece of

FIG. 104.—Enlarged view of electrode for Fig. 103.

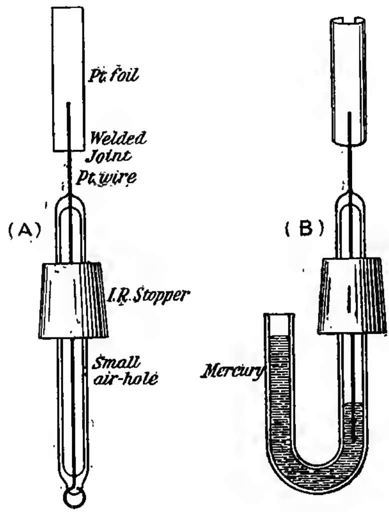


FIG. 105.—Enlarged views of alternative electrodes for voltameter.
N.B.—The small air-hole in (A) is to permit the expansion of the air during the sealing of the lower end.

platinum foil (see p. 61), and to pass this through a single-holed indiarubber stopper. The glass carrying the electrodes may be sealed into the tube, as in Exercise 12, but this is additional work to little purpose, it being an advantage for the tubes to have removable and replaceable electrodes, for cleaning and other purposes. The platinum wire may be sealed into the tube, as shown in Fig. 104, leaving a loop for the battery connection, or it may be wrapped round a stout copper wire and soldered, the tube being subsequently bent in the form of a **U** and partly filled with

mercury. In this case, the copper and platinum wires are first joined (soft solder being satisfactory for this purpose), the platinum foil welded to the platinum wire, a nick made with cutting pliers upon the copper wire where it is intended ultimately to be broken, and the whole inserted into a partially closed straight glass tube, which is then shrunk upon the platinum wire carefully, in order to avoid melting the soldered junction. The copper wire is then broken at the nick by a slight twist, pull, and rocking motion, such as the tube will permit, and finally the tube bent into shape and bordered. This method has the advantage that a convenient junction for bare wires is made without the fear of breaking off a delicate platinum loop either during an experiment, or in cleaning, while it needs much less platinum to make a satisfactory junction. Where the saving of platinum wire is not all-important, the electrode may be constructed as shown in Fig. 105 (B).

To increase the surface of the electrode, the platinum foil may either be wrapped into a hollow cylinder around a glass tube (Fig. 105 (B)), or be crinkled by being bent backwards and forwards over the edge of a piece of glass plate, and subsequently pulled out a little in the shape indicated in Fig. 106, either being performed after welding on the connecting wire.

FIG. 106.

EXERCISE 18.—*To make a platinum-tipped jet.*

This is a simple exercise, without which, however, this section would be incomplete.

Cut a piece of platinum foil 2 cm. × 1 cm. and roll it round a stout pin, or knitting-needle, so producing a tube 1 cm. long. This may be heated while still on the needle, in the blowpipe flame, and welded together by smart light blows as already described (see p. 61), though this welding is not really necessary.

FIG. 107.—Platinum-tipped jet.

A piece of glass tubing 5–3 mm. diameter is then constricted somewhat at one end by drawing out while thickening, as in Exercise 1, and the tube cut off where the diameter of the bore will just permit the introduction of the platinum tube. The needle is withdrawn from the platinum tube, which is half inserted in the glass one, and by carefully heating the glass round the inserted portion it may be shrunk evenly upon the platinum, producing a jet similar to that in Fig. 107.

The needle will serve to hold the platinum axially should it show a tendency to move.

EXERCISE 19.—*To make a percolator.*

Take a piece of 26–24 mm. glass tube, about 30 cm. long, seal up one end hemispherically, and without allowing it to cool, join to it a 10-cm. piece of 12–10-mm. tube, by pressing the two together while red hot, and well softened, blowing alternately in each end and heating the junction strongly until quite secure. Before cooling, seal in to the side (near the bottom) of the wider tube a small tube 3 mm. external diameter, and about 30 cm. long. Bend this tube round, take it up the side of the wide tube, turn it about 10 cm. from the junction, and let it return by the side of the first portion.

Blow out an opening in the side of the lower piece of tube and seal in a second piece of the narrow tube bent downwards on the

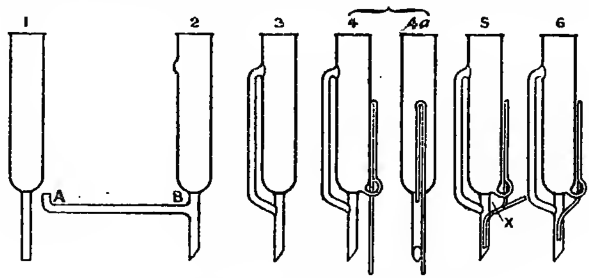


FIG. 108.—Stages in the construction of a percolator.

inside, held in place meanwhile with a perforated cork, arranging the portion outside parallel to and touching the down pipe already connected to the upper tube, as shown in Fig. 108 (5).

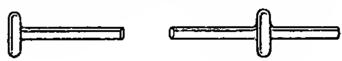
On the opposite side join in at right angles a piece of 10-mm. tubing, bend this, carry it up, and join in at the top, as shown. The lower curve must be heated at the time of pressing together the tubes to make the upper junction, consequently the order of procedure will be—

(1) Blow out the upper opening; (2) bend the tube at right angles, at A, and cut off at the correct length; (3) bend again at right angles at B, and keep A hot meanwhile; (4) press together at A, keeping B hot; (5) seal up the joint and allow all to cool.

The last joint to be made is that between the two small tubes.

These lie side by side. They are to be cut off with a single stroke of the file, and one of the curves heated until the two ends so produced come into exact line and touch each other at some conveniently accessible place, such as X. The apparatus is clamped in a stand, and the blowpipe flame is then projected against a small portion of the junction, and a thin glass rod held ready to touch the junction, should the glass tend to separate. As heating proceeds, the glass will fuse and usually fall together, when a puff of air will prevent collapse. Then another portion of the circle is dealt with, and similarly until the joint is completed all round. It should not be necessary to draw the ends together by the fused rod, but it is well to be prepared.

Glass Rod is worked as may be necessary much in the same way as tubing, but of course it cannot be blown. Two pieces to be joined are heated strongly, pressed firmly together, and while still strongly heated are gradually drawn out until the original diameter (or that required) is reached. A distension on a rod (Fig. 109, (*b*)) may be made by heating and pressing together, and an end (Fig. 109, (*a*)) may be formed by heating and pressing upon a block of charcoal.



(*a*) FIG. 109. (*b*)

Lead Glass.—This material has largely fallen into disuse, though in some ways it was more easy to work than soda-glass, being less liable to crack on cooling. Soda-glass has, however, been so much improved recently that almost all the advantages of lead glass are secured without its drawbacks—of which the principal is discolouration in the usual (reducing) blowpipe flame.

Lead glass is worked in a roaring or "brush" flame, as distinguished from the quiet flame used for soda-glass. Much more air is required to produce this oxidizing flame, and the same blowpipe rarely produces both flames correctly at will. A special blowpipe is thus required capable of giving a small oxidizing flame, and under these circumstances all the exercises described above may be performed with lead glass.

Jena Glass Tubing is very hard, and is recognized by a

blue tint observed on looking through a quantity of it. Thus the ends of a Jena tube are blue, but little if any colour is noticed by looking across the tube.

This particular tubing is difficult to work, and there appears to be a great deterioration on prolonged keeping—such tubing cracking when suddenly placed in a blowpipe flame.

To cut the tube it should be wrapped with moistened paper applied in two parallel strips with a space of about $\frac{1}{8}''$ between, as described on p. 71, heated between these with a blowpipe flame, and plunged under water. All cut edges should be rounded before use, and if possible, bordered by inserting and rotating a carbon cone in the hot tube.

Jena glass can only be worked—*i.e.* bent or blown—in the oxy-gas flame, a somewhat difficult flame to work with owing to its small size and high temperature, the latter being sufficiently high to devitrify the glass if kept long under its influence.

By means of an oxy-coal gas flame, or even an oxy-ether flame, it is possible to blow bulbs, make **T** or **Y** pieces, and perform several of the operations already described for soda-glass work with almost equal ease, though it is difficult to obtain glass of convenient dimensions.

It should be remembered that an oxy-coal gas flame can be produced by supplying the ordinary blowpipe with oxygen from a cylinder through a regulator instead of air from a blower. The flame to be aimed at is a long, noiseless one, practically colourless, and intensely hot, particularly near the blowpipe—the absence of nitrogen in the flame making it almost solid, and removing the hottest point from two-thirds of the length of the flame from the blowpipe, to about one-twentieth of that distance.

The heat being so great, it is difficult to keep the glass from devitrifying if this point of maximum temperature be freely used; consequently it is well to use the flame half way up, and gradually bring the work nearer the blowpipe as the higher temperature is needed, taking care, however, not to localize the heat too much unless this is specially

desired—*i.e.* rotation should be rather more rapid than with soda-glass.

Jena glass should not be brought into an oxy-coal gas flame too rapidly—care should be taken that it is heated up slowly and regularly, finally with great care advancing it to the hottest portion of the flame.

It may be well to remind students that while Jena glass is refractory so far as the action of acids and alkalies is concerned, and while it resists rapid changes of temperature, the glass is not for these reasons specially *strong* in the ordinary acceptation of the term. The placing of a litre Jena flask full of water upon a grain of sand on a table will frequently result in the shattering of the flask into very small pieces. Moreover, these flasks are unable to resist much difference between internal and external pressure. It would appear that the glass is under considerable molecular stress, is consequently rather more dangerous to work with than ordinary glass, and requires therefore more care. Its many advantages, however, more than compensate for these disabilities.

Fused Silica.—This material is prepared by the frequent fusion and quenching in water of "rock crystal," or quartz, the purest kind only of which is used. It is very refractory, but being light, transparent, practically unacted upon by acids, and able to withstand great and sudden fluctuations in temperature, it is rapidly displacing Jena glass-ware, and even ordinary glass and porcelain vessels from the best laboratories.

Silica is worked in the oxy coal-gas flame, and will be found capable of manipulation in much the same way as glass, but the eyes need the protection of blue glasses during work.

Tubes and rod of this material are now supplied by most dealers in apparatus, and owing to the great demand for the ware, its manufacture has been commenced on a large scale, and the price of the material has been considerably reduced of late. Silica rod, pulled out into very fine threads by means of a rotating wheel, or an arrow shot from a bow, produces quartz fibres which are therefore now within the reach of the smallest laboratory.

Broken apparatus of fused silica may be repaired by fusion

of the broken portions before the oxy coal-gas flame, and small extra pieces of the material may be added and fused in where necessary. Some little practice at the work is necessary for the securing of good results, but so far as small articles are concerned, little difficulty will be experienced by a fair glass-worker using bought silica rod and tubing. Large work is extremely difficult to handle, and somewhat costly, owing to the large amount of oxygen consumed.

SECTION IV

GENERAL

I. The Labelling of Bottles.

Few teaching laboratories need as many bottles nowadays as they did a decade ago, but it would appear still necessary to offer a practical suggestion in the matter of keeping laboratory reagents in order.

There are several points which may be regarded as absolutely essential—

1. The labels should be distinct and easily read.
2. The labels should not come off in washing the outside of the bottles, or even upon prolonged soaking.
3. The labels should not be acted upon by reagents.
4. The labels should be removable by some simple process if necessary.

It would appear at first sight that these desiderata are so contradictory as to be beyond fulfilment, save by more or less unsatisfactory compromise, though many devices have been brought into being purporting to fulfil these requirements.

The requirement of permanence is only valid at the wish of the user—consequently sand-blasted labels, etched labels and enamelled labels are excluded. At the same time it is well, perhaps, to note the various services which such bottles perform far more satisfactorily than any other, viz. the holding of bench reagents, and strong acids and alkalies. It is well to secure a good quality, as several most unsatisfactory types are on the market; the only perfectly satisfactory ones apparently being those supplied by Messrs. P. Harris & Co., of Birmingham

and Dublin, which have a white label with black letters. These do not chip, nor corrode, and after some years' wear are as good as new. All bottles of this type should be protected by a guarantee; the correct bottle *can* be secured, but there is no way of distinguishing it when new from the bad quality.

The strong acid, alkali, alcohol, and ether bottles in any laboratory should have such labels, but these are, as a rule, too expensive for use as ordinary reagent bottles, though unquestionably the best. Bench reagent bottles sometimes have their labels sand-blasted on them, clear letters on a ground surface. These soon become invisible; it is not only a matter of difficulty to read them, but it is very easy even when aware of this difficulty to mistake chloride and carbonate bottles. A third type of label is that where the glass is deeply etched, and some more or less soluble compound filled into the depressions so made. This compound disappears in time, and in any case makes the bottles unsatisfactory in the washing. The transparency of the glass, again, is a point of disadvantage, and of all these types of label none is so thoroughly satisfactory as the black letters enamelled on white ground.

For special cases, then, let us have such bottles—for strong acids, alkalies and similar liquids which are in constant use; but there will be numerous bottles to be labelled, which are not listed in this type, and these labels must therefore be supplied in MS. upon gummed blanks. The usual perforated gummed and varnished books of labels are very unsatisfactory, they all must of necessity be alike, and a run upon any special label will thus result in the destruction of a large number of books. Again, the most common of the substances have two or three copies of their label, but these are not usually sufficient—the books are made up from the point of view of labelling a newly furnished laboratory, and replacements have not nearly sufficient consideration paid to them. It is the rarest thing to see one of these books even half used—quite fifty per cent. of the contents ultimately being wasted. At the same time it is difficult to design a book of labels that would meet the requirements of every laboratory, for some schools and colleges "run"

on a different set of substances from others, according to the views of the teaching staff, and one would not willingly see this altered. Consequently no single set of printed labels will ever be economical, convenient, and universal. It would appear, therefore, that some alteration in our labelling system would be advantageous, and a suggestion is appended for what it is worth.[1]

It does not appear advantageous to purchase varnished labels. These rarely adhere well to glass, unless they are specially cemented—which one may do with dilute acetic acid cement—the reason apparently being the inability of the paper to swell and so absorb the gum when wetted, previously to their application to the bottle. Unless cemented to the bottle, therefore, they are in the habit of peeling off. At the best there are the edges of the label absorbing moisture, and open to attack by acids, etc., consequently this type of label, however

[1] Label printers should issue *two* books—

(1) A book drawn up for the purpose of fitting out a laboratory newly furnished, and while avoiding excessive duplication, at least three sets of "class" reagent-bottle labels might be included, and two sets of the rarer chemicals usually stocked for reference. Several pages of half labels should follow—the bases alone, and the acid radicles alone, one page entirely filled with half labels of one kind, so that one might detach the bottom member of each page in making up a complete label, instead of having to cut from the middle of a page. Formulæ would, of course, be deleted, but this would be little loss—one occasionally sees hydrochloric acid written H.C.L.—and might be supplied, if necessary, in MS. It would thus be as easy to pick out nickel hydrocarbonate, as sodium silicate, and extraordinary combinations would be as easy to secure as ordinary ones, and that without cutting up the book unduly. The one essential would be that the type-setting should be exact, so that alignment of type and marginal ruling might be accurately preserved, and that the space between the basic and acidic portions of the name, as well as the total size of the complete label, should be constant.

(2) A second book should contain labels for bench reagents—three copies of the acids, two of alkalies, and one of each other required. These would, as a matter of course, be omitted from the first book, and in fitting up a twenty-bench laboratory, two dozen of the second and two copies of the first would fully equip the bottles with name plates, and deal with all replacements that might ordinarily be expected to occur, while Book I. would deal with lecture work, special work, and research equipment until the whole book was used up completely.

treated, can be regarded neither as satisfactory nor permanent —many kinds indeed will not withstand ordinary washing.

On the whole, a well-gummed, unvarnished label is to be preferred; the more so, as if printed varnished labels are used it is practically impossible to secure uniformity owing to the necessity of supplementing with MS. labels. At the same time some preservative is necessary, and two fairly successful methods of dealing with this are in use.

1. *Sizing and Varnishing.*—The labels are gummed, applied, and allowed to dry; then brushed over with a weak solution of gelatine and allowed to dry again. A thin coating of transparent paper varnish is then applied, overlapping the label by about $\frac{1}{8}''$ all round, the result being a clean and bright label, impervious to the attack of water, acids and alkalies, but giving way under the action of alcohol, benzene, turpentine, and similar liquids. Such a label has the disadvantage that the varnish is liable to crack or chip if too thick or if subjected to rough handling, and the process necessitates the withdrawal of the bottle from service for two or three days.

2. *Waxing.*—This process is much more simple and convenient than that given above—a bottle may have an old label removed, a new one affixed and protected, and be returned to service in a couple of minutes. Having gummed the label, one end is fixed to the bottle and the other end left free, the label being gradually pressed from the fixed end until completely attached, in order to squeeze out all air bubbles. This is most important.

A quantity of pure white paraffin wax is then melted in a porcelain dish and heated until it begins to smoke. At this stage a flat brush is immersed, and, in a few moments, is stroked rapidly across the label, commencing about $\frac{1}{8}''$ over the edge, and finishing the same distance over the opposite edge. If the appearance be streaky, the wax is not hot enough, while if the label become transparent, it is too hot. There is only about 10° C. difference between these two temperatures, and the correct temperature is best found by experience, as it appears to vary with different operators. Practice will enable a label to be accurately and neatly covered in two or three strokes

(on no account should more be used), and the result is a clean, white and permanent label, impervious to the action of all reagents, and all liquids, save ether and benzene. The labels are removed when required by scraping with a sharp knife.

The above process was recommended by Professors Clowes and Coleman, and has proved the most satisfactory during twenty years' experience of all kinds of labelling.

II. The Silvering of Glass.

Several excellent methods for silvering glass are available, making easy the construction of hygrometers, galvanometer mirrors, convex and concave mirrors, reflectors, and other useful apparatus. There are two difficulties—

1. The silver does not always come down bright.
2. The silver frequently prefers to deposit upon the sides of the containing vessel rather than upon the desired object.

The first is a chemical, the second a mechanical trouble, each to be solved in its own way.

1. The choice of a formula depends much upon circumstances, but in the main an ammoniacal solution of a salt of silver is reduced by some organic reducing agent. The following method works very well provided the solution of tin chloride is freshly made, clean, and dilute, otherwise the silvered surface is likely to be of a dark colour—

A. Dissolve 2·5 grams silver nitrate in 100 c.c. of distilled water; reserve about 25 c.c. of this solution, and add ammonium hydroxide solution to the larger bulk until the precipitate at first formed *almost* redissolves. The precipitate disappears rather suddenly at the end, hence the advisability of reserving a portion of the original solution. The 25 c.c. reserved is then treated similarly and added to the rest, the whole being filtered and made up to 250 c.c.

B. Dissolve 0·5 gram silver nitrate in distilled water, and pour into 250 c.c. boiling distilled water. Add 0·4 gram Rochelle salt, and boil the mixture till the precipitate is grey.

Filter while hot, and keep both solutions in well-stoppered bottles in the dark.

The surface to be silvered must first be cleaned by thoroughly washing in strong caustic potash solution, then dilute nitric acid, finally in distilled water. Between each washing the surface should be rubbed with a soft wet duster (cheese cloth is the best material for this purpose). A solution of stannous chloride in water to which a single drop of hydrochloric acid has been added is then poured gently and evenly over the surface, and the object well washed in tap water, taking care not to touch the prepared surface with fingers or duster after the treatment with tin chloride.

While still wet, the object is placed in a waxed dish (see below), and a mixture of equal volumes of the two solutions already prepared quickly poured over it, avoiding splashing and air-bubbles; and if possible avoiding a direct stream upon the prepared surface. In about an hour the silvering will be complete, when the liquid may be poured off, the article cleaned and dried, and the apparatus cleaned up.

The silvered surface should not be touched with the fingers, and when quite dry may be varnished with very dilute shellac varnish, but the varnishing of deposited silver is always dangerous, owing to the contraction of the varnish upon drying.

Gutta-percha dissolved in benzene is said to be free from this defect, a varnish recommended for this purpose being—gutta percha, 5 parts by weight; gum dammar, 20 parts by weight; benzene, 75 parts by weight.

Stains may be removed with a pad of cheese cloth dipped in dilute nitric acid.

2. The difficulty of the silver depositing upon surfaces where it is not required is overcome by waxing these surfaces. A porcelain dish, for example, may be heated, some paraffin wax melted in it, and run round the hot dish, and the excess poured off. Silver will not deposit upon such a dish.

A convenient receptacle for silvering is easily made by folding a piece of waxed paper—prepared by dipping into melted wax a sheet of thin unglazed writing paper until bubbles cease to come away, then draining from one corner

and allowing to set[1]—into a box, without cutting or tearing, and cementing the edges by heating.

The solution should be about an inch deep above the object to be silvered.

Two other formulæ are here appended—

1. Due to Mr. G. S. Newth.

A. 90 grams sugar candy
4 c.c. 1·22 S.G. nitric acid
175 c.c. of alcohol.
Made up to one litre with distilled water.
N.B.—This solution will keep.

B. 1·8 grams silver nitrate is dissolved in distilled water, and ammonia solution added until the brown precipitate nearly redissolves. 0·9 gram caustic potash dissolved in water is then added, and the precipitate again nearly redissolved in ammonia solution. Make up to 180 c.c.

For use, add 10 c.c. of solution A to the 180 c.c. of solution B, pour quickly over glass prepared as directed above. An hour is required for silvering.

2. 2 grams of silver nitrate crystals are dissolved in 70 c.c. distilled water, and ammonia solution added till precipitate just dissolves; 1 gram of Rochelle salt is then dissolved in 33 c.c. distilled water, mixed with the first solution immediately before use, and poured as before into the silvering vessel. The silvering will take half an hour, in a warm place, and the deposit is hard and bright, so that it may be polished with rouge.

Polishing should, however, never be attempted until the silver is perfectly dry, and then be done very lightly indeed with a pad of cotton-wool.

[1] This paper is extremely valuable for many laboratory purposes—it is an excellent electrical insulator, enables magnetic fields to be demonstrated with iron filings (and by holding a hot iron over such a map it may be made permanent), and is invaluable in building condensers, etc.

III. Plaster Casting.

The main usefulness of this art is in the preparation of models, of certain specimen duplicates, and to provide moulds in which may be cast lead weights suitable for pendulum, lever, and other experiments.

As an example of the first, we may take the manufacture of a composite cube consisting of six square based pyramids.

Set out on stiff drawing paper or thin white cardboard, a square on a 2″ base, and construct the development of a square based pyramid, the height of which will be 1″. The correct

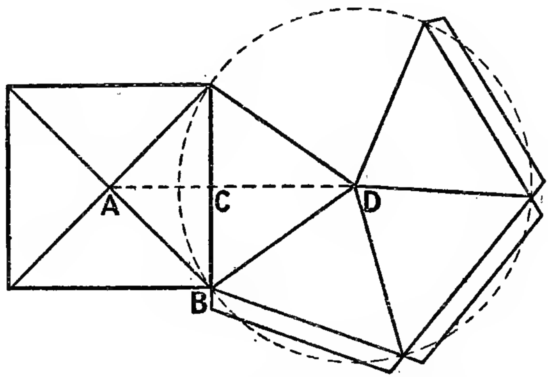


Fig. 110.—Development of square based pyramid.

N.B.—By an oversight a flange upon the second side of the last face has been omitted in the above sketch.

length of the edges may be found geometrically by joining a point 1″ from A along the diagonal AB to either of the ends of the other diagonal of the square. With B as centre, and this distance as radius, cut AC, the bisector of the angle at A, at the point D, which is the centre of a circle on the circumference of which the bases of the remaining three faces are set off. Join to D and add all necessary flanges.

With a sharp knife score all the edges, and bend into shape, touching the flanges with good glue, and attaching them on the *inside* of the pyramid.

This is the model, of which six copies are required.

Take a sheet of brown paper—or, better still, waxed paper—and fold it into a box, without cutting, by taking a piece,[1] $12'' \times 8''$, folding a long strip $2''$ wide down each side and $4''$ wide across each end. Then double up one edge and one end, fold back the projecting corner behind the upper end, do the same on the other side, and fold down the remaining $2''$ strip to hold all in place. Repeat at the other end.[2] If made of waxed paper, the whole can be fixed by the application of a hot knife-blade. Brown paper may need sealing-wax.

Take about 500 c.c. of water in a basin or other wide-mouthed vessel, and scatter into it two or three handfuls of superfine plaster of Paris, stirring well with a steel spatula or similar flat instrument. Continue adding the plaster until a thin creamy mixture is obtained, when stirring should be discontinued. The paper pyramid should now be well rubbed with oil, or melted vaseline, and the surface smoothed down carefully. Pour the mixed plaster into the box, and when almost full, press down the model, base upwards, into the plaster, permitting it to rise and fall several times in order to get rid of air-bubbles, and finally hold it in position by placing two knitting-needles across the box top, against which the model will float. (Hatpins are very useful in this connection, as they may be inserted through the side of the paper box.) Then fill in the plaster until it shows a tendency to creep over the edges of the model and run on to the base. Allow the box to remain untouched until the plaster is quite hard—overnight, if possible.

At this stage the model may be removed—a matter of little or no difficulty in this case, as there are no undercuts, and the paper will have become softened so that it will come away from the plaster quite easily. The mould should be dried either by standing in a warm, dry place, or in a water oven at 100° C.

Having fined the corners down, and made any necessary alterations to the mould in order to remove the effects of bad

[1] The size of the paper will vary with the size of the object. Boxes of any shape and depth may easily be constructed on this plan.

[2] Boxes such as these, of good writing paper, will hold water while it is boiled over a gas flame.

contact, air-bubbles, etc., pour into the still warm mould some melted vaseline, and remove any not absorbed by the porous surface. On no account should this be attempted while the mould is damp.

Proceed then to fill the mould with a mixture of plaster of Paris and water prepared exactly as before, smoothing the top with a spatula, to form the base of the new pyramid. In a few hours the pyramid may be removed by inverting the mould, and shaking, or by gently inserting the blade of a spatula between mould and cast.

Five similar pyramids may then be similarly cast, and the cube completed.

The faces of these pyramids will probably be somewhat stained, but a few strokes upon a sheet of fine glass-paper (not *with* the glass-paper) will give them a clean, white surface, provided they are perfectly dry before this is attempted. Models such as this, which have to withstand fairly rough usage, are greatly improved by a soaking in boiling paraffin wax, removing while still hot, immediately after effervescence has ceased.

The process outlined above may be varied in order to produce moulds of spheres, coins, medals, and other objects, used for casting lead, plaster, sulphur (which produces excellent casts in warmed moulds) and other substances, useful in numerous ways in the laboratory. Sulphur, being an excellent electrical insulator, may be by these means made up into extremely useful units of electrical demonstration apparatus, and in any required form. Moulds for casting sulphur should not be vaselined, as the cooled sulphur comes away quite easily, provided the temperature at casting has been below the viscous point; though it will have been necessary to heat above this temperature in order to secure uniformity of fusion.

Lead may be cast in warm, dry plaster moulds, being melted for the purpose in a porcelain dish over a Bunsen flame. No injury will be done to the dish if dry.

IV. Electrotyping.

In the copying of models and small parts of apparatus it is frequently of service to be able to copy an object in metal successfully where casting would be impossible. The electrical deposition of copper is, moreover, the only way in which satisfactory electrical connection can be made between carbon and metal surfaces, or quartz fibres and other parts of instruments successfully mounted.

In order to study the method, however, it will be well to take some simple example, *e.g.* to make an electrotype copy of a coin or medal. The method may then be applied to the solution of any specific problem when it occurs.

To make the mould,[1] soften a quantity of shredded gutta-percha in hot water, and knead it into a pad free from air-bubbles; place this in the middle of the surface of the medal to be copied, and gradually press it towards the edges in order to exclude all air between medal and mould. When the edges are reached the gutta-percha is pressed tightly down upon the medal, covered with a sheet of paper, a second sheet being placed under the medal, the whole placed between two wooden blocks, and tightly gripped in a vice till quite cold. The mould is then hard and solid, but may be removed from the object by bending slightly, when a perfectly bright and smooth-surfaced mould should be obtained. A plaster cast may be taken from this mould in order to test its completeness and accuracy, as it is often difficult to detect slight differences and deviations when the relief is reversed.

For electrotyping, the surface of this mould is now to be made electrically conducting. This is done by powdering a quantity of ordinary blacklead, mixing to a paste with water, and smearing the paste over the inner surface of the mould with a stumpy camel-hair brush—an ordinary one with two-thirds of the hair cut away at right angles to the axis will serve the purpose admirably.

[1] A mould may he made in fusible metal by pouring it over the surface of the *warmed* object. The copper is deposited *all over* such a mould, and this is wasteful, but can be stopped by waxing the part not required to be coppered.

Every corner having been blacked, the blacklead is polished with the tip of the third finger until every portion shines brightly, taking care to include the edges of the mould, and a margin of about half an inch all round the actual mould of the medal. A hole is now to be pricked with a bradawl inside this margin, and a piece of copper wire threaded through and coiled round the gutta-percha, blacklead being well rubbed into the hole in order to make good contact between the copper and the blacklead film. Too much attention cannot be paid to the securing of a perfectly continuous, smooth, and bright surface of blacklead, as upon this the whole success of the process depends.

It may be well to note here that bronze powder is frequently recommended in preference to blacklead, but this material is very liable to be put on too thickly, with the result that upon immersion into the plating solution the whole film strips. In addition, even when this does not destroy the film completely, there is a tendency for a connective column of fragments to form upon the surface of the plating liquid, and "short" the leads. It is found, however, that if bronze powder be mixed with a little benzene, and the mixture *painted* on the mould—it must be done rapidly, or the gutta-percha will become partly dissolved, and its sharpness entirely spoiled—success may be achieved. The surface is, however, liable to be lumpy, and, all things considered, the blacklead process is to be preferred.

The wire attached to the mould is now connected to the negative pole of a (pint) bichromate cell,[1] and the positive pole connected to a sheet of copper, the mould and copper being then dipped under the surface of a slightly acidified solution of copper sulphate in water (100 grams cryst. $CuSO_4$, 250 c.c. water, 2 c.c. H_2SO_4) mould and copper plate facing each other about an inch apart, and parallel to each other. The zinc of the cell is now gradually dropped into the exciting liquid, when a current

[1] Chromic acid should be used as the exciting liquid in the "bichromate" cell rather than bichromate of potash and sulphuric acid. The best formula is 5 oz. (avdp.) chromic acid, 3 fl. oz. conc. sulphuric acid, water to 40 fl. ozs. To this 5 grams of mercury dissolved in the minimum quantity of conc. nitric acid, evaporated to dryness, and redissolved in water, may be added, this serving to keep the zinc amalgamated.

passes from the copper to the mould, depositing copper upon the blackleaded surface near the wire, and gradually spreading to the whole mould. It should be noted that the amount of copper deposited is proportional to the amount of current, not to pressure, hence no advantage accrues through the use of more than one cell, the resistance of copper sulphate solution being small; while the condition of the deposited copper is perfectly under control by the amount of zinc allowed to act in the cell. If the zinc be fully let down, the amount of current (proportional to surface acting) will be large and the deposition rapid, in which case the copper is often deposited in a flocculent condition, in which state it is useless, as it does not adhere to the blacklead. On the other hand, too slow a deposition will probably produce a crystalline coating, so much time being taken in the process as to make it a nuisance. About $\frac{1}{2}''$ of zinc let down into the solution is generally sufficient, and, in this condition the process may continue overnight, when the coating of copper should be complete, and of a bright red colour. The resistance of the liquid may be increased and the rate of deposition decreased by increasing the distance between the plate and mould, the copper coming down brighter and more closely adherent at the greater distance. In any case the plate and mould should be kept parallel, or one portion of the deposited copper will be thicker than the other.

The deposition having been completed, the mould may be removed from the cell, the copper portion dried, filled up with solder, with zinc chloride as flux, and cleaned up with benzene —the gutta-percha will soften and peel off under the influence of the heated solder. The copy may be polished by rubbing with (*a*) benzene, (*b*) powdered bathbrick, (*c*) precipitated chalk, (*d*) rouge, and trimmed and mounted as desired.

Carbon-metal junctions are easily and satisfactorily made by depositing copper upon the carbon in the manner indicated above, the carbon being attached to the negative pole of the cell, and immersed in the plating solution to the depth to which the copper is required. The carbon is removed after deposition, dried, and the coppered portion soldered to a

copper strip or a copper wire, wrapped around several times, and the whole "sweated"[1] together.

A good exercise is the manufacture of a constant E.M.F. (ferric chloride) cell.

A piece of arc lamp carbon 12·5 cm. long is drilled along its axis for 1 cm., and at an angle of about 110° to its axis at the end of this hole. The carbon is then connected to the negative pole of a cell, and immersed in a copper-depositing cell to a depth of 2 cm., so that the whole of the drilled-out passages are coated with copper. The deposition being completed, the carbon is removed, cleaned and dried.

A freshly scraped No. 20 copper wire is pushed down the axial hole, along one of the side holes, and pulled through for about 15 to 20 cms. This is then wrapped round the carbon several times, and the free end finally inserted into the second side hole, making a neat and secure job. The junction is then well soldered, the hole through which the wire passes being completely filled up with solder.

This carbon is secured at a distance of about 2 mm. to a piece of hoop iron 12·5 × 2·5 cm. interposing rubber or wood of the required size, and binding the two pieces together with twine. A second piece of No. 20 copper wire is soldered to the hoop iron, and the resulting element, immersed in a 10 per cent. solution of ferric chloride, will give a constant E.M.F. of from 0·75 to 1·0 volt.

Quartz fibres (or glass fibres, which form a reasonable substitute in many rough forms of apparatus) may be similarly treated. They are coated with blacklead by rubbing between finger and thumb, immersed in a plating bath, as above, and copper deposited for about an inch from the end. This is then dried, dipped in zinc chloride solution, and stroked through a bead of solder upon a hot soldering iron. The support is tinned and the fibre soldered in place without trouble.

Unnecessary copper may be removed with a piece of cotton-wool dipped in nitric acid.

[1] *I.e.* heated before the blowpipe in presence of $ZnCl_2$ and soft solder.

V. The Cleaning of Mercury.

The method adopted to this end will largely depend upon the history of the mercury. It may at once be stated that any mercury which has been used for amalgamating zinc battery plates had either better be kept solely for that purpose in future, or if by accident a quantity of such mercury becomes mixed with a large stock, practically the only satisfactory method of cleaning will be that of distillation. It is said that mercury contaminated with zinc can be cleaned by shaking with sulphuric acid, but experience points in the contrary direction.

Mercury which has become dusty through much use in glass tubes may be cleaned by means of a separating funnel, or, what will serve the purpose equally well, a dry filter paper in an ordinary funnel, filled with the mercury, and having a tiny hole pierced with a needle at the bottom of the filter cone. It is astonishing what improvement the liquid will exhibit after so simple a process, and also what a quantity of dirt this process will remove. The mercury must never be forced through the filter paper—nor even tapped to make it run more freely; such action will carry dirty mercury through.

The filter cone may be refilled until all the mercury is dealt with.

Should the liquid still leave a "tail" when run over a sheet of paper, it should be shaken with concentrated sulphuric acid in a strong well-stoppered bottle, when it will become granular, exposing a great surface to the action of the acid. The contents of the bottle should, after several such shakings, be poured into a large quantity of water, and the mercury collected in a porcelain dish, dried with blotting or filter paper, and again tested. If not yet satisfactory repeat with dilute sulphuric acid, or place it in a funnel drawn out to a very fine point, and dipping into a long jar filled with dilute nitric acid. The jar —or wide glass tube—should be at least 3′ long, and the mercury should come through only in the smallest of beads. A jar is conveniently made of a length of 1″ diameter glass tubing. After several passages down such a tube, the mercury

may again be tested, and if still insufficiently cleaned and purified nothing short of distillation will suffice.

Many devices are on the market for the distillation of mercury; many of them doubtless very good, but a six-ounce Jena retort, heated by a Fletcher argand gas-ring, and surrounded with an asbestos millboard jacket, produces the greatest yield at least cost, both of apparatus and trouble. The retort is rested on wire gauze, and the asbestos millboard is cut so as to surround the bulb of the retort, and the top is almost covered with a sheet of millboard having two slits or holes about 1″ diameter pierced through to let the heated gases escape. No cooling arrangements are necessary, but it is necessary to cool down the apparatus before the addition of fresh mercury, and it is advisable not to use more than 3 lbs. of mercury at a time, as bumping is dangerous to the retort in such case. Of course, the whole of this apparatus is stood meanwhile upon a tray, so that in event of a breakage no loss of metal may occur. Slow distillation with a fairly small flame is the most satisfactory.

It is a good plan to keep a separating funnel partly filled with concentrated sulphuric acid, into which all laboratory mercury residues are put immediately after use. The mercury drawn off from the bottom of such a funnel is usually in excellent condition, and needs no preparation before use.

VI. Care of Laboratory Ironwork.

The fumes in a laboratory cause considerable annoyance by their effect upon ironwork, which needs almost constant attention in consequence. The usual method is to coat the ironwork annually with Brunswick black, and this is a source of annoyance during the rest of the year to any one who has to use apparatus so treated. Retort stands, clamps and rings, tripod stands, Bunsen burners, and similar appliances must be protected, and it is a matter of importance to choose some method that will give satisfaction to all concerned.

For the above ironwork, if a black enamel be required, nothing better can be obtained than the "Eggshell black,"

sold by Hobbies, Ltd., Dereham, Norfolk. This appears to be a superior kind of Berlin black, quite different from the ordinary Brunswick black, in that it has quite a remarkable "covering" capacity, and that it dries almost instantly to a hard matt surface, clean and serviceable in every way. Certainly it burns off when heated, but in doing so, it produces no offensive smell, and is no inconvenience in any way.

For ironwork which is subjected to water-splashes, Eggshell black is not so suitable, as it shows stains and dirt rather badly owing to its colour, though it is easy to give another coat from time to time. The paints supplied by the Metallic Compositions Co., Ltd., of Gray's Inn Road, London, are excellent in such cases—the most suitable, perhaps, being the aluminium paint which is able to withstand the action of either heat or water. In our own laboratory the special composition made to withstand heat has proved able to withstand acid fumes equally well, and a good deal of ironwork is coated with this composition in consequence; an instantaneous water heater with gills and brass tubes being coated with the composition, and being as good now after eighteen months' duty as the week after it was put on. There is some slight odour when first the gas is lighted, and some dulling of the appearance, but after this little alteration appears to take place, and a composition that will resist the heat of the gas flame, and preserve its cleanly appearance above a large sink in a constant atmosphere of fumes and moisture has much to recommend it.

The same firm markets a preparation of a similar nature of the colour of gunmetal, and this may be painted over laboratory water-taps and similar gunmetal fittings, with advantage to their appearance if they have been allowed to become corroded, or are past burnishing and polishing. A really smart appearance may be given to an old laboratory by the use of a few shillings' worth of the above preparations, the only difficulty is that science teachers, as a rule, have no time to deal with these matters, and that a laboratory attendant, where present, frequently lacks the skill and pride necessary

for the production of a reasonably successful result. However, after a few experiments, work such as this ought to be within the power of every laboratory attendant.

VII. Care of Bench Tops.

Bench tops are usually made of teak, and it has already been stated that a fortnightly treatment with a mixture of equal volumes of *raw* linseed oil and turpentine, well rubbed in, and finally rubbed dry will keep all such tops in excellent condition without danger of causing stickiness. The oil must be *raw*. Boiled oil will produce a skin on the bench—which is a source of endless trouble, and can only be removed—as it must be—by scraping.

Bench tops were made, years ago, of cheap wood—pine or deal—and paraffin wax was melted in with hot irons. Benches such as these are impervious to the action of water, and to some extent of acids, though attacked by strong acids and by alkalies. Little is gained therefore by this treatment, which is difficult to renew, difficult to preserve or improve when stained. It also has a tendency to become inconveniently highly polished, and to "sweat" under the influence of reflected heat from a sandbath, for example.

VIII. Useful Cements.

Cements are used for attaching one surface to another. The objects to be cemented may be similar or dissimilar, and may be rough or smooth; consequently they will need different treatment.

The action of a cement is to hold together various substances in such position relative to each other as to permit mutual attraction. The joint is always much stronger than the cement, though it could only be of the same strength as that of the cement if a complete layer of cement separated (or joined) the surfaces. The obvious moral is that small quantities of cement only are to be used in every case, and that the surfaces to be joined must be pressed tightly together in the presence of the cement, in order to reduce the quantity to a minimum.

With some cements, such as cementium, which has the property of setting into a hard mass upon exposure to air, it is possible to "build in" spaces between materials to be cemented, but this is not possible with glue, or other examples of true cements.

The kind of cement chosen, therefore, will depend upon the nature of the work to be attempted.

Acetic Acid Cement.[1]—For broken glass, porcelain, or similar hard substances, which break with a clean surface. Take a quantity of gelatine, and allow it to soak in cold water until it has absorbed about its own volume. Add about half the total volume of glacial acetic acid, heat until homogeneous, when it will be ready for use. If in cooling it does not set into a stiff jelly, add more gelatine and heat again. The cement is applied with a wood splint, to the warmed surfaces, previously cleaned and dried. When cemented, the article is squeezed together, tied round with string if possible, and left for twenty-four hours, when the excess of cement may be scraped off, or removed with a cloth soaked in hot water.

Treacle Glue.—For ground surfaces. Make up a quantity of strong glue, by soaking ordinary glue overnight in cold water, pouring off the remaining water, and melting the glue by immersing the jar containing it in a saucepan of boiling water. Add to this one-fifth its weight of black or common treacle, and stir well. The glue is applied hot, and on cooling a firm and watertight joint is formed. The mixture does not keep.

Bichromate Glue.—For glass or porcelain joints which have to withstand the action of hot water. Prepare a quantity of strong glue as before, and add to it, when melted, one-tenth of the weight of powdered bichromate of potash. Keep at a high temperature until the bichromate is dissolved, when the glue will be ready for use. Exposure to light helps the cement to harden.

Liquid Glue.—For leather and glass, leather and iron, leather and wood, etc. Add to a strong solution of glue about

[1] For mending broken glass apparatus of large size, after cementing use may be made of the gummed linen strips sold for the repair of music, subsequently painting the strip with shellac varnish.

one-twentieth its volume of strong nitric acid. Keep well corked and in the dark.

Chatterton's Compound.—This is purchased ready made; it is used for cementing dissimilar substances, iron and wood, leather and wood, etc., though it makes a water-tight joint on a glass cell well, if applied to ground surfaces. The method of application is to heat the surfaces to be joined, melt the Chatterton at the Bunsen flame (not ordinary gas flame) spread a little over the surface, heat again, and spread with a splint of wood until the whole surface to be cemented is covered with a thin layer of cement. The second surface is similarly treated, the two heated fairly strongly, and well pressed together—in a vice or under a heavy weight if possible. When cool, the joint is trimmed.

A good cement to take the place of "Chatterton" is made by melting a quantity of flake shellac in an iron ladle and stirring in twenty per cent. of "oil of cassia."

Shellac.—Shellac is one of the most useful of cements; it may be used alone, in the same way and for the same purposes as Chatterton's compound, or it may be dissolved in methylated spirit and used as a varnish, or in stronger solution used direct, as a cement. In any case the object should be cleaned, dried, and heated before the application of the shellac.

Cement for Celluloid.—Dissolve some celluloid scrapings in acetone. The liquid will clear upon heating slightly, and is then ready for use.

Vulcanite shavings dissolved in sulphuric ether will also answer the same purpose.

Miscellaneous.—A useful cement for fixing brass rings to glass cylinders, etc., is made by mixing five parts resin, one part beeswax, one part red ochre, at a high temperature, and allowing to cool. The cement is applied hot, in the same way as Chatterton's compound.

For fixing pestle handles nothing is better than melted resin, as it appears able to withstand the percussion shocks better than any other substance. A little teased-out twine or hempen rope should be *loosely* wrapped round the pestle stump, to prevent the resin cracking.

Fusible metal composed of—

40 parts by weight of bismuth.			
20	,,	,,	lead.
10	,,	,,	tin.
10	,,	,,	cadmium.
15	,,	,,	mercury.

is said to cement glass securely to metal, as also will some solders, particularly the one recommended for aluminium.

It is sometimes of advantage to have a wax for the temporary attachment of indicating needles of straw or paper, and this wax should be sufficiently soft to admit of squeezing into any desired shape, and should easily and firmly adhere to any material upon which it is pressed. Waxes of this kind are easily made by mixing in suitable proportions various hydrocarbons belonging to the same class—paraffin wax, vaseline and paraffin oil, for example. A few trials will soon enable any one to mix up a wax suitable for his particular purpose, and this more easily by trial than by weighing out definite quantities.

IX. Paints, Stains, Varnishes.

Paints.—Only one or two of these need be mentioned. Laboratory stands, of wood, are frequently painted black with a mixture of lampblack and shellac varnish. The saturated shellac varnish is diluted to about half strength with methylated spirit, and is used to mix with a quantity of lampblack while this is being ground in a mortar. When perfectly fine the ground lampblack is mixed into the shellac and spirit solution until an opaque dead black coating is obtainable at a single application. The mixture is kept well stirred while being used.

A white enamel is made by mixing 3½ lbs. of white lead, ground in oil, with half a pint of "inside" oak varnish, and stirring well. It must be kept well stoppered when not in use. This will be found quite satisfactory for painting numbers upon benches, etc.

Stains for Woodwork.—1. Mahogany stain is made by dissolving a small quantity of Bismarck brown (aniline dye) in rectified spirit, and pouring the solution into warm water. The strength of solution may be varied to suit varying requirements.

2. Walnut stain is made by mixing a quantity of Vandyke brown (ground in water) in a mortar, with strong ammonia solution, pouring off the resulting solution into a well-stoppered Winchester quart bottle and repeating the addition of ammonia solution and the stirring until all the solid disappears. The solution so obtained is suitably diluted with water, and shaken.

3. Permanganate of potash dissolved in water produces a walnut-coloured stain on wood, but owing to the action of the acids in the wood the colour is fleeting.

4. Bichromate of potash solution stains oak a dark brown, and is used in producing "fumed oak." A dilute solution of ammonia has much the same effect, but this is not permanent, though, curiously enough, the stain upon oak produced by shutting it up in an airtight box containing also a saucer of 0·880 ammonia solution, is permanent; oak may be darkened to blackness by this treatment.

5. Green oak or ash may be produced by treatment with solutions in water of various aniline colours; in each case the colour must first be made up in rectified spirit, and added to water. "Aniline green," "seal brown," "diamine yellow," judiciously mixed, will produce a pleasing colour free from the crudeness frequently shown by "stained green" furniture.

6. A stain for the imitation of pitch pine may be made up by mixing a little burnt umber with yellow ochre, in turpentine and raw linseed oil, while without the burnt umber an imitation of yellow pine is obtained.

It will be noticed that in each case, save No. 6, water stains are recommended. Spirit stains are very deceptive, difficult to apply, and produce unsatisfactory results. They rub off when dry, and dry many shades darker than they appear while being applied, consequently the greatest disappointment frequently results from their use. It is almost impossible to French polish satisfactorily over a spirit stain.

Water stains, however, are more dilute, they go on evenly, and one does no damage by moving over the same spot twice. They dry very little darker than they appear when applied, and subsequent varnishing usually restores the lost brightness. They have the objections that they "fetch up the grain" (*i.e.* roughen the wood somewhat) and take longer to dry, but the certainty with which they may be used is more than reparation for these disadvantages.

Varnishes.—One or two only need be mentioned.

1. *Shellac varnish.*—This is the principal one used for the preservation of laboratory woodwork apart from fixtures. It is made by soaking flake shellac in methylated spirit till soft, gently heating and allowing to stand after a good shaking. If a powder settles, more spirit is added, until a clear liquid is produced. This is suitable for the varnishing of linen strips, joints mended by cements, mirror backs and delicate apparatus of that kind, for insulating coils of wire, and for lacquering brass. For mending and cementing, however, a much stronger solution is required—practically a saturated solution being the best. This is made by placing 1 lb. of shellac in a jar, covering with methylated spirit and allowing to stand for several days, with frequent shaking. The liquid so produced may be used for painting on coils of wire for insulating purposes, and may be coloured black for negative leads by the addition of lampblack, or red, for positive leads, by vermilion.

It is very serviceable for varnishing wooden "patterns," models, and wooden stands and appliances in general; indeed, there is no more useful laboratory preparation than this.

2. *Sealing-wax varnish.*—This is made by dissolving the best sealing-wax in methylated spirit, and if not sufficiently brilliant, adding a little vermilion and shellac varnish to the solution. It is used for painting corks, iron magnets, insulated coils, and various electrical apparatus.

3. *Silicate varnish, white paper varnish, dark oak varnish,* had each better be purchased as required. The former is useful for painting bright articles (nickel, gunmetal, etc.), which it preserves from atmospheric effects, and the uses of the others have already been described.

X. Burette Stopper Grease.

The most suitable grease for this purpose is made by melting together equal parts of resin cerate and vaseline. The mixture is only applied to a perfectly dry stopper, and a smear is all that is required. It is placed on either side the bore, and the stopper slipped into the dry barrel of the tap, pushed home, and rotated until the whole becomes transparent. If this does not happen, remove the stopper and add a little more grease. The usual fault, however, is that of using too much grease.

XI. Polefinding Paper.

One gram of phenol phthalein is dissolved in absolute alcohol, poured into 100 c.c. distilled water, containing 10 grams pure potassium chloride.

Filter paper strips are then soaked in the liquid and hung up to dry. When two electrical leads are placed close together upon a piece of moistened prepared paper, the negative pole shows a red stain.

XII. Litmus Solution.

Litmus solution is spoiled by heating. It should be made by extracting the solid litmus with cold distilled water, and it should be preserved in bottles which allow access to the air, otherwise the colour will disappear.

XIII. Coloured Liquid for Experiments in Hydrostatics, etc.

The best substance for this purpose is fluorescin. A 1 per cent. solution of the solid in spt. vini. rect. is kept in stock, and a few drops added to the bulk of water. One drop per litre is sufficient to produce an easily visible colour, and the apparatus may be washed clean without trouble afterwards. It does not stain or cause any trouble, and is easily visible, even in very dilute solution.

XIV. French Polishing.

This is a method of preserving wood from atmospheric influences, which adds greatly to the appearance of the work.

It is not difficult of accomplishment, but considerable time must be devoted to the acquirement of the skill necessary for the performance of the operation with certainty and complete success. It is easy to do, but difficult to do well.

Before commencing the actual polishing, the surface must be prepared, and this process will differ considerably according to the nature of the wood.

Soft woods—Basswood, yellow pine, cedar, etc.—polish badly, *i.e.* the polishing requires much more time, energy, and material, and the result is more transient; it is difficult to attain a permanent high polish upon a soft wood.

Hard woods—oak, walnut, mahogany, etc., polish well—a little polish and little time being sufficient to produce a hard, bright, and lasting surface.

The difference appears to be due to the nature of the wood fibre rather than to the porosity of the wood itself, as some porous woods, *e.g.* mahogany and oak, polish well, but these have hard fibres.

All woods must have their pores stopped before polishing, and of course no plane or tool marks should be visible, as these will show up with far greater persistence after polishing.

Soft woods may be brought up to a "fine" surface by the use of progressively finer grades of glass-paper; but hard woods should be scraped to a fine surface before being glass-papered, and then only the finest grades of paper used.

Glass-paper will, to some extent, fill up the pores—the fine "dust" removed by the paper being rubbed into them. As fine a surface as possible having been obtained in this way, hard woods are treated by rubbing in a mixture of whiting and raw linseed oil, preferably stained with some suitable colour matching the natural colour of the wood. Soft woods should be simply oiled. The rubbing should be done with a linen cloth, and the oil or mixture of oil and whiting,

well rubbed in, finally the remainder wiped off, and the work allowed to stand a while.

"Red oil" is frequently used by professional French polishers, and this appears to be a mixture of raw linseed oil, spirit, bichromate of potash or some similar oxidizing substance. The object is the same as that above—to stop up the pores (if only temporarily), and so allow the polish to remain on the surface.

It will save time if soft woods are painted at this stage with shellac varnish and a little raw linseed oil. This mixture penetrates a little, but quickly dries, and as the spirit evaporates, a layer of shellac remains which prevents the entry of the polish that is to follow. On drying completely, the whole surface is glass-papered down again, and a second painted coat given, and glass-papered as before when hard. The surface should then be hard and perfectly smooth. Hard woods may receive a similar coat, but this is really not necessary, and very little time is saved by such treatment, as the subsequent glass-papering removes practically the whole coat.

Having now secured a hard and smooth surface, the actual polishing commences. The object of French polishing is to put upon the wood a thin film of shellac, and to burnish this by pressure while it is in that peculiar state of semi-solidity or pastiness which the shellac exhibits during the instant immediately preceding the total evaporation of the solvent. The film of shellac applied is, however, so thin that the condition approaches and passes very rapidly, and in the "nursing," of this condition to cover the whole surface simultaneously, much of the polisher's skill is centred.

The method of securing this film is as follows: In the centre of a linen cloth some ten inches square is placed a pad of cotton-wool, about nine cubic inches in size before compression. This pad is saturated with a solution of shellac in methylated spirit (or, better, in rectified spirit), the linen cloth is wrapped round it so as to enclose it totally and allow no single fibre to stray, and by holding it in the right hand and patting it against the palm of the left hand, this is

shaped into a suitable pad for polishing. Before applying it to the wood, however, two or three drops of raw linseed oil must be placed exactly upon the spot that will be in contact with the wood, in order to prevent its sticking to the semi-solid surface. The pad is at once rubbed backwards and forwards along the outside edges of the surface to be polished, without sufficient pressure, at first, to cause much liquid to flow through the linen cover, and the whole enclosed surface covered with a circular motion, until each part has been treated. Then in long swinging strokes, in the direction of the grain, the pad—now freed from much of its solution—is pressed a little harder upon the wood, a little linseed oil being added now and again as before, until presently a slight pull is felt upon the pad or "rubber." This is the time to polish, which is done by slightly increasing the pressure upon the now almost dry pad or rubber, and continuing the circular motion, after every few strokes wiping the edge of the surface, in order to prevent liquid trickling over the edge, and making an unsightly mark upon the still unpolished portion.

Presently the stickiness will increase so that it may be difficult to move the rubber easily across the surface; more oil, applied instantly, will cure this, and the pressure should be gradually taken off until the well-oiled rubber is moving about the surface as lightly as at first. In these few moments the true polish appears, and, when satisfactory, should be left, the whole operation being repeated upon another face until the object has received one complete coat. In warm weather, or in a room at 60° F., a coat should be left an hour before being again touched, after which it may be glass-papered with some well-used very fine glass-paper, until practically the whole of the polish is removed. If this temperature be not easily attained, the work should be left a longer period without touching, then glass-papered down as before.

A second, similarly applied coating of polish will give the required surface almost at once, with very little pressure, and a third, after once more glass-papering down, will practically complete the "bodying-up" of the work, and indeed with the result so obtained most of us may be content, the

"finishing" being a process possible only by so long a practice as to be almost beyond our attainment.

Each coat of polish should be put on more lightly than the last, less pressure and less polish being necessary as the true surface is obtained.

Finishing is a somewhat tedious process. It consists in using more and more dilute solution at each successive stage, drying and glass-papering in between each as may be necessary, for French polish should never be a *veneer*, merely at most a surface, until finally pure spirit (spt. vini. rect.) alone is used on the rubber. In the hands of the beginner this invariably results in the complete destruction of his previous work, but this is usually caused through using too moist a pad—the pad for these last stages being almost dry, save for a little oil.

Where cheapness and extreme gloss are essential, various substances—such as gum benzoin—are used towards the end of the process, but though these produce a wonderful surface at the time, it is somewhat soft, and the gloss fades, leaving a polish inferior to that obtained by the first process alone.

Polish applied according to the above instructions upon oak, walnut, ash or other hard wood will be as good in twenty years as at first, but it will not be as bright as that secured by a professional polisher—though probably less fleeting.

Great care should be taken to include the edges of any surface being polished, in order to spread out evenly any of the solution that may be squeezed over the side. Should this happen and pass unnoticed, nothing short of entire removal by glass-paper can remedy the fault.

XV. Graduation and Calibration of Apparatus.

The calibration of apparatus is usually undertaken after it has been graduated, as many operations are more easily accomplished then; but it is easily seen that the calibration should come first, save that this would entail a large amount of extra trouble. Glass apparatus is rarely constant in volume, it alters

as time passes, and to such an extent that thermometers, for example, are commonly kept from three to five years before graduating and marketing. In these instruments the fixed points are determined, the distance between divided into a hundred parts and the scale duly marked. The assumption, therefore, is that the tube is of equal diameter throughout, and care has been taken to ensure this, any tube in which this is not the case being rejected in the manufacture of thermometers. Similarly with burettes, the zero is commonly marked, water is filled in to the mark, 50 grams run off, a new mark made, and the distance divided into fifty equal spaces. In modern instruments successive 5-c.c. are taken, and one may frequently trace a faint line at successive 5-c.c. marks, where the graduation has been checked. It will be seen, however, that to graduate a tube according to its true calibration would entail an enormous amount of work, and would lead to very expensive apparatus (which, after all, no chemist would trust; he would surely recalibrate his instruments), consequently the method adopted is to divide the extremes into an equal number of parts, and find the true value of each—say, once a year or so.

It is not uncommon to graduate a tube in millimetres, as this can easily be copied from a steel scale in the manner described below, and to calibrate afterwards.

We may for our purpose describe the method of graduation and calibration of (*a*) a pipette; (*b*) a burette; (*c*) a thermometer. From these, it will be easy to arrange the details of any other calibration exercise that may fall to the lot of an experimenter.

(*a*) *A pipette.*—A pipette is an instrument for delivering the amount of liquid engraved upon it, and may easily be made by a student of glass working. Since it has to deliver, and not to contain its rated amount, calibration can only be accurately carried out by treating the instrument in the way in which it has to be used. Thus it is of no value to weigh the pipette full and empty, but it must be used to deliver the exact amount of its rating, and this must be measured; the delivery taking place exactly in the same manner in which the instrument is to be subsequently used.

A stoppered weighing bottle is weighed, the stem of the pipette stroked with a brush full of melted paraffin wax, and a mark scratched through this with a needle at right angles to the axis of the tube. Water is filled into the pipette in the usual way, and emptied from the mark into the weighed bottle, drained five seconds, and the last drop blown into the bottle. The bottle and water are then weighed, and the difference shows the amount of water delivered from the pipette under the conditions of using. The number of grams of water is, of course, divided by the density of water to obtain the volume of the pipette. Should the result not correspond with that desired, the mark is moved up or down the stem, and a second experiment made, and so on until the exact spot is found. Usually three trials will be required before success is reached—the first and second giving the relation between length of stem and volume discharged, the differences being, of course, proportional; hence a simple calculation should show where the correct mark is situated, and a third trial should justify this.

The correct position having been marked, the whole stem and bulb of the pipette is covered with wax, all previous marks being obliterated, the correct mark alone piercing the layer of wax on the stem. The mark should be continued in a circle completely round the stem, and the number of cubic centimetres delivered by the pipette written, through the wax, upon the bulb.

Filter paper is then cut of such size as to well cover the various marks—a strip $1'' \times \frac{1}{4}''$ for the stem, and a square covering the writing for the bulb. These filter paper strips are then saturated with a solution of hydrofluoric acid, applied to the pipette, allowed to stand ten minutes and kept moist with the acid if necessary. The filter paper is then washed off, the glass well washed, and the wax removed by heating and wiping with a dry cloth. The marks should be properly etched on the glass, and appear *white*, not transparent, as would be the case if the acid were applied in liquid form.

(*b*) *A burette.*—Pinch-cock burettes may easily be made and graduated by any student who cares to follow the directions

given below. A burette is graduated first, and calibrated afterwards. The graduating is a very awkward performance, as it involves the dividing of a line into a large number of equal parts, and the accurate transfer of these small divisions.

The burette is an instrument used to deliver large amounts of liquid in small quantities at a time, hence it must be graduated by a method which gives accuracy under such conditions.

The stem is waxed as before, and a mark made high up, for the zero point. A dry weighed beaker or weighing bottle is next taken, the temperature of the water to be used determined, and the mass of 50 c.c. of water calculated. This weight is then recorded, being added to those already in the balance pan, and the water is filled into the burette, up to the zero mark already fixed, the bottom of the meniscus being coincident with the mark. If preferred, a burette float may be used. The water is now allowed to drop from the burette into the weighing bottle—a drop at a time, until roughly the 50 c.c. have escaped, when the bottle and contents are weighed. A few drops (say 20) are again allowed to fall, and the bottle again weighed. A simple calculation will now give the number of drops still required to complete the 50 c.c., and these are allowed to fall, tested by weighing, and corrected if necessary. The burette is now marked through the wax, and the 50 c.c. volume recorded. This has now to be divided into ten equal fives.

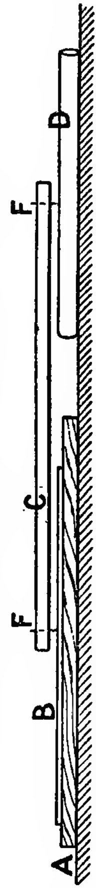


FIG. 111.—Use of the beam compass in the graduation of glass instruments. A, wooden support; B, scale; FF, needles piercing the beam; C, beam; D, waxed glass tube.

With a fine pen and in good black ink draw a long line upon a piece of drawing paper well stretched out upon the bench, and transfer to this line the distance between the two marks, by placing the marked burette upon the paper along the line, and pricking down with a sharp needle at each mark, dividing the line so

made by some simple geometrical method, perhaps the best being that of opposite equal angles. Each division has again to be divided into ten equal parts, and this may be performed similarly upon a separate piece of paper, the scale so produced being exactly cut out, and superposed upon each division of the larger scale in turn, the subdivisions being pricked through—a simple matter if care be taken to get the ends absolutely correct.

The strip of paper used as above is to be divided into tenths by a similar method, but it is best to transfer the whole cubic centimetres to the burette first. This is done by one of two methods.

A. Cement the burette down to the bench with Chatterton's compound, and take a pine rod about 1 metre long, pass through it two stout darning-needles (see Fig. 111, FF), ground down to rather stumpy points, one near each end. The needles should project about 1 cm. through the beam. Fix the paper scale to the bench in line with the burette, so that the 0 mark on the scale is immediately underneath one of the needle points when the other is on the zero mark of the burette. With one needle upon the 0 mark on the paper, scratch through the wax with the other; move to the second mark and scratch the waxed burette again, and so on until the whole burette is marked.

B. Place the burette upon a wooden platform with a squared face (A), and cement in place as before. Cement

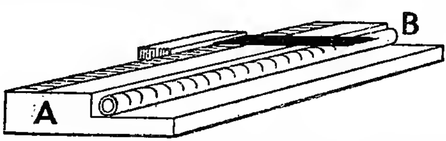


FIG. 112.—Straight-edge method of transferring graduations to glass tubes.

the scale already made on the upper surface, and by means of a steel straight-edge, pressed against A, as shown in Fig. 112, the marks may be transferred to the burette. The exact manner of doing this is to take a stout needle (a knitting-needle ground to a chisel edge), place it at a point on the scale, move the

straight-edge up to it, lift the needle, maintaining constant inclination, and mark the burette. Repeat the whole process for each mark transferred.

In either case the tenths have now to be filled in. This is accomplished by dividing a number of cubic centimetre divisions on the small detached piece as before, and securing it successively in convenient positions on the main scale with two needles placed at the end division but one of the small scale, and pricking through, in each case, exactly to a whole-number mark upon the main scale. By this means the division of the whole scale is avoided, and sufficient accuracy obtained.

The whole divisions having been marked—large scratches for the whole numbers, smaller ones for 0·5 c.c., and smallest for the 0·1 c.c. marks—proceed to number from the top downwards, making the numbers as small as possible, and the shapes distinct. See Fig. 113.

1234567890

FIG. 113.

Remove the burette, wax all portions not intended to be etched, mark if desirable initials and date of graduation, paint all marks with a brush dipped in hydrofluoric acid solution, so as to remove air-bubbles, and fix filter paper strips dipped in hydrofluoric acid solution upon the marked portion of the burette as before, making quite sure no air-bubbles exist underneath the filter paper. After ten minutes, wash, heat, remove the wax, clean up with benzene, rub the burette with a mixture of white lead, plaster of Paris, and boiled linseed oil until the etched marks stand out plainly; wipe with a dry cloth, and proceed with the calibration.

Calibration is performed by filling the burette up to zero mark with distilled water, noting the temperature before and after the experiment, determining the density of water at the mean temperature, and weighing successive 5 c.c. in a dry beaker, or weighing bottle. The 5 c.c. must in each case be drawn off slowly, as the burette will be used in this way.

The weight divided by the density of the water will give the

true volume, and a table (or curve) representing the figures obtained should be constructed and referenced to the burette in some unmistakable manner.

The burette readings and the actual volumes may either be tabulated vertically, which will enable one to add the volumes to any required total, or they may be placed so as to give total error to any required point, which method would, of course, necessitate the refilling of the burette to zero, after each titration.

SPECIMEN TABLE.

Burette.	Actual volume.	Total error.	True reading.
c.c.	c.c.	c.c.	c.c.
0–5	4·95	−0·05	4·95
5–10	4·97	−0·08	9·92
10–15	4·99	−0·09	14·91
15–20	5·00	−0·09	19·91
20–25	5·01	−0·08	24·92
25–30	5·01	−0·07	29·93
30–35	4·99	−0·08	34·92
35–40	5·01	−0·07	39·93
40–45	5·03	−0·04	44·96
45–50	5·04	−0·00	50·00
	50·00		

Method A.—The last column figures are taken as correct for the 5 c.c. immediately before the reading, the burette reading beyond this being added.

Example.—Burette reading	.	28·7 c.c.		
Previous 5 c.c.	.	25·0 „	True vol. =	24·92 c.c.
		3·7 „		3·7 „
		Corrected reading	.	28·62 „

Method B.—The "total error" of the previous 5 c.c. mark is algebraically added to the burette reading.

Example.—Burette reading	. . .	28·7 c.c.
Total error at 25 c.c.	. .	0·08 „
Corrected reading	.	28·62 „

It will be seen that the second is the simpler method, and it has the additional advantage that one may, without calculation, take the *nearest* 5 c.c. error instead of the previous one, without any calculation.

(*c*) *A thermometer.*—The thermometer consisting of a single tube only will be considered, other types being now more rare, the only difference in method being in detaching the measuring thread.

The stem of the thermometer will have a thread of mercury showing. About 10° (or 3 cms.) from the top of this thread the thermometer is heated with a tiny gas flame, produced from a piece of millimetre tube (thermometer tubing). The mercury thread is carefully watched, and will be found presently to break away from the main thread at the hot point, when the instrument should be immediately withdrawn from the flame.

By means of a reading microscope, the length of this thread is carefully measured at various positions along the bore, the length varying with the volume of the bore, and though the actual volume cannot be determined, numbers proportional to the volume and in terms of degrees may be found in this way. From these a table of corrections should be drawn up, giving the correction to be applied at each 5°.

XVI. The Making of Scales upon Glass.

This process is very simple, and after the previous exercises requires little description.

(*a*) *A flat linear scale.*—A piece of glass is obtained and coated with wax, by warming the clean dry glass strip, brushing wax upon it with a wide brush, and holding in a slightly inclined position until cool. The back and edges are similarly coated, and the glass cemented to the bench either alongside a steel metre scale or in a line with it.

The steel straight-edge (or try-square) is used in the former case, and a wooden, needle-pointed beam compass, described above, in the second.

The transfer of the marks should, however, only take place after ruling four parallel lines upon the strip, with a ground

knitting-needle as before, when the marks are transferred exactly as previously described in the case of the burette.

The scale should then be numbered, and if it is to be used for measuring upon, the zero mark should not be the first but the second (see Fig. 114), as any fractional number may then always be taken from the same part of the scale, and the fractional division of the rest of the scale is unnecessary. Thus to measure 3·4, one leg of the dividers would be placed upon 3, and they would be opened until the other reached −0·4; while in measuring 2·7 the fractional portion would be taken from the same divided unit, consequently the possibility of error would be greatly reduced. Should the scale be required

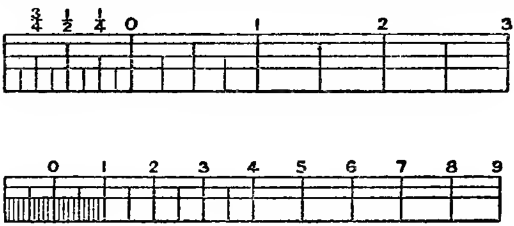


FIG. 114.

for lantern use, for light spot work, or needle indicator work, however, it will need dividing throughout its whole length.

When the transference of marks is completed, the waxed brush may be applied to any marks which have been accidentally carried too far, and any other necessary obliterations made in the same way. Name and date being added, a strip of filter paper is cut as before, so as to cover the scale well, soaked in a solution of hydrofluoric acid, and applied to the scale. Any air-bubbles under the paper must be removed by light pressure with a brush, or a plug of cotton-wool in the end of a glass tube. The supply of hydrofluoric acid should be liberal, but not so copious as to cause it to flow over the edges of the filter paper.

After ten minutes' treatment the paper is removed, the scale well washed, heated, wiped clean and dry, polished with benzene, and if perfect, rubbed with red lead, plaster of Paris,

and boiled linseed oil. After wiping clean, the edges of the slip may be ground and polished.

(*b*) *A circular scale, upon glass, paper, or metal,* is made in a similar manner by the use of a graduating table. This consists of a hardwood base into which a graduated brass circle has been sunk, and a rule one edge of which is coincident with a radius of the graduated circle (see Fig. 115). The paper, glass, or metal is firmly fixed to the board, and the rule applied, the circles or segments drawn, and marks transferred *along the radial edge* with some suitable instrument—a drawing pen for paper, a sharp stylus, as previously described, for waxed glass, or a graving tool for metal. The rest of the process is simple, consisting mainly in cleaning up and burnishing. Instead of being engraved, brass may be coated with wax, and etched with nitric acid (two parts 1·4 S.G. acid, one

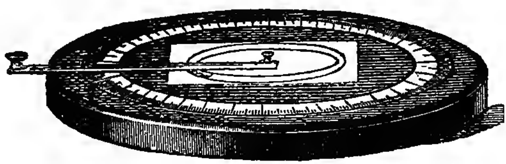


FIG 115.

part water); cast iron and steel may be similarly treated, but with sulphuric acid, or copper sulphate solution if an actual etching of the surface is not desired.

Engraved scales in brass may be silver-plated by suspending them in a solution of silver cyanide and potassium cyanide, connected to the negative pole of a 4- or 6-volt battery, and immersing in the same liquid a silver plate connected to the positive pole of the battery, in the same way as the electrotyping was performed previously.

The solution is made as follows:—20 grams crystallized silver nitrate are dissolved in 100 c.c. distilled water, to which 0·5 c.c. pure nitric acid has been added. A saturated solution of potassium cyanide in distilled water is then prepared, filtered if necessary, the volume determined, and the solution added carefully to the silver nitrate solution until the precipitate

first formed just redissolves. Note the volume of cyanide solution used, and add to the preparation one-tenth in excess of that already used. Make up the solution to 1 litre, and shake up well with 5 c.c. of carbon disulphide, allowing the liquid to settle, and filtering before use.

The brass should be well cleaned, washed in hot dilute caustic potash solution, and then in cold water several times. Finally, it is to be immersed momentarily in a 1 per cent. solution of mercurous nitrate, and well rinsed before plating.

The silver should be rather heavily deposited, and cleaned up by polishing first with a brush made by binding about a hundred 6-inch pieces of fine brass wire into a bundle, and wrapping tightly with brass wire to within half an inch of each end; then polishing with powdered rotten stone and oil, and finally with rouge. Otherwise the silver may be burnished after "scratch-brushing" with the wire brush, in the manner already indicated for burnishing silver.

A powder composed of one part by weight of silver nitrate, two parts potassium cyanide, and five parts of precipitated chalk, ground finely together, and applied to brass with a moistened rag, will cause a layer of silver to be deposited on the surface of the brass, but the layer is very thin, and wears off readily. In some cases, however, the application of this preparation may save electrolytic deposition, though the electrical method is well worth the extra trouble.

APPENDIX I

THE MAKING OF LANTERN SLIDES

THOUGH this is not strictly a "Laboratory Art," the science teacher will find it a great convenience to be able to prepare his own slides almost at a moment's notice, and the application of the lantern to his teaching will be greatly extended.

Lantern slides may be prepared in several ways, but roughly these may be segregated into four main groups.

1. Slides prepared by photography.
2. Slides prepared by tracing or sketching on ground glass and subsequently "clearing" by various methods according to the requirements of the case.
3. Slides prepared by tracing or sketching upon ordinary plain glass with special ink.
4. Slides consisting of mounted objects, such as crystals, leaves, etc., usually, however, more suitable for projection with the aid of a lantern microscope.

1. In some cases the "negative" may be suitable for the making of a lantern slide without further trouble, and in many ways the manufacture of lantern slides may be shortened according to the purpose of the product, but the following method will give a fairly complete outline of the full process, from which departures may be made as the exigencies of time and material demand.

The process of preparing the negative will vary according to the object being photographed. Apparatus is difficult to photograph owing to reflections in the glass parts, while books are difficult because of the trouble of holding them in position during photography, and at the same time efficiently lighting the page to be copied.

Apparatus should be set up on a bench out of the reach of direct sunlight, but in a position of fair illumination—if possible it should not be placed facing a window. The more diffused the

light, the better will be the negative secured, but at the expense of shortness of exposure. A background of neutral tint—grey or purple-grey—composed of a ground colour painted on stretched canvas mounted upon a wooden frame, should be provided.

The colour may be prepared as follows:—Take 2 lbs. of "ball" whiting, mix with half a gallon of water, and stir till no lumps remain. Add to this 8 ozs. of glue, soaked in cold water for twenty-four hours previously to use, and melted in the soaking water (which should only just cover the glue) by immersion in a pan of boiling water. Stir well and add 1 oz. of ultramarine, finely powdered, and enough red ochre or sesquioxide of iron to "kill" the blue colour and produce a neutral grey tint. Lampblack ground in water containing a little methylated spirit may be added to darken the shade if necessary. The whole preparation is then

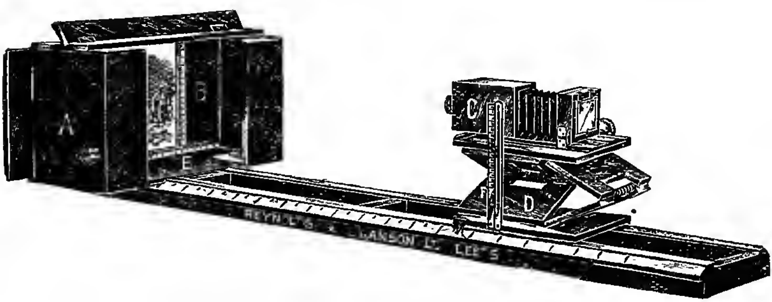


FIG. 116.—Lantern slide making apparatus.

well stirred, and applied with a coarse brush, such as a whitewash brush, to the stretched canvas, the spaces in which will be filled up by the mixture. When the first is dry, a second coat, containing slightly more water than the above preparation, may be given. All materials must be finely powdered, and ground with water before mixing.

The apparatus, mounted in front of this neutral background, is then photographed in the usual way, using a small stop, and giving a long exposure.

Diagrams or book illustrations may be photographed similarly, while supported between two retort stands, and held in position by the clamps, in which case the burning of 3 inches of Mg ribbon on each side the lens of the camera is the most satisfactory method of illumination. Messrs. Reynolds and Branson, Ltd., of Leeds supply an exceedingly convenient apparatus for the photography of

book illustrations, but the graduations appear to be carelessly made. It is, however, the most convenient and handy camera and appliance for this purpose, and saves its cost very quickly, inasmuch as more and better work can be done by its aid. It is illustrated in Fig. 116.

The best plates to use are those prepared by certain firms specially for the manufacture of process blocks. For apparatus and similar work Ilford "half-tone" plates have been found most satisfactory, while for the photography of diagrams, sketches, book illustrations in black and white, etc., Ilford "Process" plates cannot be excelled. The whole success of lantern-slide making (*i.e.* line work) depends upon securing a negative giving the sharpest possible contrasts, and as most plates are made with the expressed intention of toning down sharp contrasts, it follows that a special plate is necessary. Any one who has tried to make good slides with ordinary plates will know the practical impossibility of doing so, while no process could be more simple, more certain, and more pleasing in its results than the following one, provided the above plates be used. "Quarter" plates will be found the most suitable for our purpose, having one dimension identical with that of the finished slide, which is $3\frac{1}{4}$ inches square.

The plate having been exposed it is removed to the dark room, placed in a developing dish, and swilled over from corner to corner, with a mixture of the following solutions; care being taken to avoid air-bubbles, and rocking the plate and dish until the picture appears, darkens, and disappears :—

A	Water	30 fluid ozs.	850 c.c.
	Hydroquinone	150 grains	10 grams.
	Metol	30 grains	2 grams.
	Sulphite of soda	$3\frac{1}{2}$ ozs.	100 grams.
B	Water	30 fluid ozs.	850 c.c.
	Carbonate of potash	6 ozs.	170 grams.
	Bromide of potash	90 grains	6 grams.
C	Water	10 fluid ozs.	280 c.c.
	Citrate of soda	150 grains	10 grams.

For development mix—

of A 2 ozs. or 50 c.c.
of B 2 ozs. or 50 c.c.
of C 20 drops or 1 c.c.

Development will proceed without the addition of C, but the plate will be more transparent, and the contrasts much less distinct.

Without the addition of citrate of soda a very ordinary negative will result, and will usually require intensification. With citrate of soda, development may be pushed until the picture completely disappears—until the plate becomes completely black. Then it is removed from the developer, rinsed quickly in a basin of water, and immersed at once in a dish containing a fixing solution, which consists of 2 lbs. hyposulphite of soda and 2 oz. metabisulphite of soda, and a Winchester quart of water. The plate is kept immersed until the back of the plate looks perfectly black, and on being held up to the light, the whole plate is clear and transparent. It is then removed to a rack, washed for half an hour in running water, drained and dried. All these operations are conducted with the plate film upwards, and only the edges of the plate may be touched with the fingers. Special care must be taken to keep the hands, bench, dishes, camera, and all appliances absolutely clean and free from the hyposulphite solution, otherwise endless trouble and disappointment will result. In removing the plate from "fixing bath," care must be taken not to allow even a single drop to fall upon bench, floor, or anywhere where it may pass unnoticed until crystallization indicates its whereabouts. Should this occur, the solid may be crushed, and sent into the air as a fine dust, settling upon the unexposed plates, which then commence to "fix" the instant they are placed in the developing solution. Pin-holes will result, and are frequently due to this cause alone. Hence frequent swilling of all dark room appliances, and the use of plenty of washing water are to be strongly recommended.

All solutions used should be at about the same temperature, consequently it is recommended that they be kept in the dark room, where the whole of the above operations are to be conducted.

The plates referred to above are capable of withstanding very rough treatment. After washing for ten minutes, for example, they may be drained a few moments, dried by wiping with a wet chamois leather, and subsequent standing before a fire. Any ordinary film so treated would melt off the glass.

Over exposure or under exposure are the principal causes of failure to secure satisfactory negatives, the other possibilities of straying being largely corrected by the use of the plates recommended, and by exposing in the manner suggested. Over exposure is detected by the rapidity with which the picture appears. An over-exposed plate shows up its picture rapidly under development, but before it has time to gather density or definition, the plate blackens, and one has to transfer it to the fixing bath. The plate so produced is "thin" and the definition is poor,—

(*a*) because the plate is insufficiently developed, (*b*) because of the blackened film above the picture. Under exposure is detected by the impossibility of securing a crisp picture though development is pushed to excess. Development should be complete in about two or three minutes, but an under-exposed plate after this time would still fail to show a good sharp picture, and further development would simply result in the "fogging" of the plate by a blackening similar to that mentioned above.

Both faults, if small, would therefore produce much the same type of plate, though experience enables one to appreciate small differences which indicate the kind of error; but no trouble should be experienced by a beginner in deciding whether his plate is correctly exposed or not while he is developing it.

Many methods exist of correcting errors of exposure to some extent, while the development is in progress, but the best advice that can be given to a maker of lantern slides is to determine by a few experiments the exposure required for a good negative, and not to vary this when found. The illumination of the object by artificial light is greatly to be preferred, as it is constant, and the distance of the camera from the object makes little difference in this case. With stop $f/22$, a 3″ length of magnesium ribbon burnt at a distance of a foot from the illustration, on *each* side of the lens (which must, of course, be protected from the direct rays of the burning ribbon) has been found to give the best results, natural light being totally screened off. An unsatisfactory negative, *i.e.* one where the picture shows, but the ground is not sufficiently dense to stop out the light when printing, may frequently be improved by the process of intensification, and as our work is not concerned with the artistic side of photography, but merely with the obtaining of an absolutely black and white copy of a black and white object, intensification cannot well be over-done.

The process is carried out as follows: After washing the negative well in running water, it is laid film upwards in a dish and a saturated solution of mercuric chloride poured over it. Care should be taken to avoid air-bubbles, and these are frequently so small as to be overlooked, consequently it may be well to brush the film lightly with the tip of the third finger while under the mercury solution, care being taken not to press heavily. The solution should contain no suspended matter, and as it may be used again for a similar operation, it should be returned to the stock bottle through a filter.

The film will become grey and then white, when an apparent reversal of the image will have taken place; that is, black lines on

a white ground appear. This is, however, not strictly the case, the black ground is certainly covered with a grey deposit, but the original white lines owe their apparent blackness now to their transparency, in contrast with the ground.

The plate is now to be thoroughly washed, and the subsequent failure or success of the negative largely depends upon the thoroughness of this washing. At least an hour in running water should be given, and as much longer as is convenient. When thoroughly washed, the plate is removed to a bath of dilute ammonium hydroxide solution (the strength does not matter much) where it blackens; the completeness of the operation being judged by the appearance of the back of the plate, which should be perfectly black. After two or three minutes in this solution the plate is lifted out, washed, drained and dried as before. The film must not now be dried before a fire or by any such method; it must be dried slowly and perfectly drained.

Rapidity in drying may be secured in all cases of plates, by soaking the plate for ten minutes in methylated spirit, and drying by exposure to air, after wiping with chamois leather. The process is not to be recommended, as in drying some transparency is frequently lost. Rectified spirits of wine does not produce this loss of transparency to quite so great an extent, but it is expensive. The best way of all is to drain and air dry.

Intensification should not be looked upon as a necessity; good negatives, and perfectly satisfactory black and white copies, can easily be obtained without this process; it must be regarded merely as a way of improving a poor plate. It is a question whether the process is really worth while, but inasmuch as it enables a poor plate to produce a good print, it is included here.

The actual lantern slide, termed a "positive" or "transparency," is now to be made. The dry plate is placed, film inwards, in a ¼-plate printing frame, and a lantern plate placed above it, the two films being in contact. The best plate on the market is "Thomas' Lantern Plate," which even the Germans use. This plate is very thin, the film sensitive and capable of producing dead black lines upon an absolutely transparent ground; not a single lantern plate of this make need ever be wasted. Having placed the positive in position, make sure the required print is in the centre of the plate, and fasten up the frame. Expose by holding up to a gas flame, 2 feet from a No. 3 Bray gas burner, for 12 seconds will usually suffice. With a thin negative take 15 seconds 3 feet away, and with a very strong negative 12 seconds at a foot.

Development and fixing are proceeded with as before, but no

sodium citrate is added to the developer. The plate should be developed until the image appears clearly upon the back, when the lines will look a little furry from the front, but this disappears on fixing. The positive should be fixed as before, washed for an hour in running water, drained and air-dried. It is then ready for masking and binding.

Masking.—Bought masks are frequently of unsuitable sizes for the masking of slides prepared from book illustrations, but it is a simple matter to cut a mask of any desired size or shape by placing the slide film downwards upon some black (or dark) "cover" paper, marking the outline of the square slide, and by means of a straight-edge and pencil, indicating at the edges of the square the position of the required opening. Four such lines being indicated, the plate is lifted, the opening cut out with a very sharp knife, and the mask cut out similarly. If a bought mask of standard size cuts out all the text not required on the slide, so much the better.

Binding.—Gummed binding-strips are sold for this purpose, the most satisfactory being the "Specialist" strip, which adheres particularly well. They should be new, however, as the compound used as adhesive deteriorates in time. "Specialist" strips are cut 3¼″ long, consequently corners are no trouble. The strip is moistened, laid gum upwards upon the bench, and the positive, mask, and cover glass (clear 8 or 10 ounce glass 3¼″ square), pressed in the centre of the strip, the edges of which are then folded upwards and pressed until they adhere to the glass. The three other sides are similarly dealt with.

2. **Slides prepared by Tracing upon Ground Glass.**—A 3¼″ × 3¼″ piece of finely ground glass is placed above the picture to be copied, and firmly traced with a hard, well-sharpened pencil ("Koh-i-noor" HHH is perhaps the most suitable). The plate is then removed to a 9″ square of brass or aluminium and heated with a Bunsen until just too hot to handle comfortably. A second square of plain glass is placed by the side of the plate and similarly heated. From a wide-mouthed bottle a quantity of filtered and partly evaporated[1] Canada balsam is poured on the centre of the plate, care being taken that in the pouring no air-bubbles are drawn into the balsam.

Some little skill is required in doing this—the object being to pour the balsam out in sufficient quantity, and to leave no stringy tails of balsam adhering to the bottle. The best way is to

[1] Prepared by evaporating on a water-bath a quantity of ordinary filtered Canada balsam, until its volume has decreased 25 per cent.

commence by trying to pour out a great deal, and as soon as the balsam begins to flow from the bottle, slice off what is required with a glass plate, and return this plate to the bottle, which it will serve to cover. The result is a globule of balsam free from air-bubbles in the centre of the ground glass plate, gradually spreading toward the edges. Remove the burner, and place the clear plate above the globule of balsam, holding it so that one edge touches the corresponding edge of the ground glass plate beneath, and allow the balsam to creep out to the edges of the plate (see Fig. 117). This may take a few minutes, but it must not be hurried, and on no account endeavour to increase the speed by pressure upon the upper plate, such a procedure resulting inevitably in disaster. When perfectly clear and free from air-bubbles, allow it to cool, remove from the plate by slipping a knife beneath the bottom glass, and scrape the excess of balsam from the edges with a piece of waste cardboard or glass. Having fairly cleaned the slide, complete the cleaning of the edges by means of a rag dipped in benzene, ether, or xylol, and bind the slide immediately. When the edges are bound the slide may be completely cleaned and polished. It is not necessary that a balsam slide should ever positively *dry*—it rarely ceases to be sticky if left unbound, but once bound it may be cleaned up and no stickiness will be apparent afterwards. Canada balsam, if used as bought, is excessively sticky, and will give great trouble in adhering to the fingers, clothes, and anything else with which it may come in contact. It is not so sticky, however, if partly evaporated, being then more of a crisp solid nature, and easily scraped off glass, etc. At the same time some care is necessary in the handling of the material, and it is well to go slowly and methodically to work.

FIG. 117.

Masks may be fixed after the slide is finished; not, as before, between the glasses, but on the outside.

Slides made as above, but for temporary use only, may be "cleared" with vaseline or olive oil. They may then be cleaned and used again.

3. **Slides made by Tracing on Plain Glass.**—Ordinary glass may be used in making lantern slides by the use of special opaque inks. Such are "Pearl" ink—a kind of Chinese ink, but this requires to be mixed with a little "ox gall"—and "Vitro ink," which is white, but opaque, and on the whole is most satisfactory for hurried work. Vitro ink is sold by Messrs. J. J. Griffin & Sons,

Kingsway, London, in shilling bottles. It is used exactly in the same way as writing ink, with a steel pen—it quickly sets hard, and is then only removed by scraping. Any drawings or writing done on glass with this ink may be converted into lantern slides by masking, covering, and binding as before. The ink is of special value in the drawing of sketches or diagrams upon a glass plate while in the lantern, thus giving all the advantages of a blackboard and a lantern slide combined.

4. **Slides made by Mounting Objects such as Crystals, etc.**—Large objects are rarely suitable for lantern slides, leaves, and similar objects being usually so thick as to produce a slide wider than the ordinary lantern carrier will accommodate. Crystals rarely form with sufficient distinctness upon a $3\frac{1}{4}''$ square plate to be worth projecting, but many such objects lend themselves to projection by the aid of a microscope.

A microscope slide is usually $3'' \times 1''$ in size, and if crystals be prepared by spreading a drop of cold saturated solution upon them, and slowly evaporating it, they may be preserved and used as slides.

A very suitable way of performing this is to use a small flat ring or "cell" made of tin, and obtainable from dealers in microscopic appliances; moisten this on both sides with "Hollis' glue" (shellac, spirit, and beeswax), place in position upon the plate, and immediately cover with a circular "cover slip," specially made for microscopic work.

Many other objects may be similarly mounted.

Projection is accomplished by fixing a $2''$ objective in a retort stand clamp, placing it in front of the condenser of the lantern so that the lens faces the condenser, at the point where the pencil of light converges. The slide is placed between this objective and the condenser, care being taken to hold it vertically. It will be seen that an ordinary microscope without the eye-piece would form an effective stage and holder for the slide and objective, and it would also screen off unnecessary light. By this means an ordinary microscope may be used for the projection of practically all microscope slides, but no objective of higher power than $1''$ is suitable for limelight lanterns; $\frac{1}{3}''$ or $\frac{1}{4}''$ may be used with the arc lamp, but considerable risk is run of damaging lens and slide by the heat, unless a lantern cell containing a solution of alum be interposed immediately in front of the condenser. This will effectually stop all the heat.

APPENDIX II

OPTICAL PROJECTION

It is not intended in this section to deal exhaustively with the projection of apparatus, etc., as several text-books on the subject exist already, but it has been considered desirable to record the main principles upon which projection depends, and to indicate the most satisfactory way of putting these principles into practice.

The units of apparatus necessary for the optical projection of slides, apparatus, and experiments, are as follows :—

1. Radiant, or illuminant.
2. Condenser—a lens for the collection of the light rays.
3. Slide carrier.
4. Objective—a compound lens for the production of the image.
5. Erecting prism, for erecting the inverted image of apparatus.
6. Polarizer.
7. Prism for spectrum.

It is not necessary for these units to be mounted up in a single appliance called a "lantern," indeed, for many experiments disconnected units are to be preferred; but, as a rule, the projecting lantern is the most convenient form of handling the various units.

1. *Radiant.*—Many illuminating devices are commonly in use, from the incandescent gas mantle to the electric arc, but it will be seen that the most suitable radiant to employ is that which most nearly gives its light from a point, otherwise numerous overlapping images will be produced, and while this is not a great disadvantage in the projection of pictorial slides, such as landscapes, etc., it is sufficient to render the projection of apparatus, and the production of the parallel beam unsatisfactory, owing to the difficulty of securing precise definition of graduation marks, etc.

For a similar reason the quadruple acetylene jet is not to be recommended. As a rule, the four separate jets will produce four separate images on the screen, and if acetylene must be used, it is better to use a single high-power jet of the duplex type than two or more separate jets.

The best radiant is thus one of high candle-power—upwards of 500 must be available for apparatus projection and erection—and small area, and the appliances which most nearly approach to this ideal are—

(1) The electric arc.

(2) The Nernst lamp (star pattern).

(3) The limelight, various patterns.

(1) The electric arc is, as a rule, obtained by an appliance specially built for lantern work, the best examples perhaps being the "Brockie-Pell," "Ross-Hepworth," or the "Phœnix" lamps, though, of course, there are others. These lamps have the great advantage of fitting standard lanterns. The electric arc may be worked at any pressure over fifty volts, and may be controlled by a number of resistance coils, or, if the alternating current be used, by a choking coil. The carbons of the lamp should be sloped at an angle of 60° or 70° to the horizontal, and the current should pass down the lamp, *i.e.* the upper carbon should be connected to the positive wire. With the alternating current, the carbons are best arranged horizontally. By this means the arc is placed so that the crater of the upper carbon throws most light outwards towards the condenser, in an equally illuminated divergent cone.

(2) Failing the electric arc, "Nernst" lamps may be used, but these are delicate, and have the serious objection of requiring a considerable time to light up. They are not recommended for general use, especially if, as is usual, the lantern is required intermittently during a lecture.

(3) The next best light is the limelight, and many variations of this are quite common. This illuminant is the most popular of all, being safe, clean, easy to handle, and of sufficient power for all ordinary work. It has the great advantage of portability, and is, of course, independent of an electric installation.

Thus we have the simplest kind, the oxy-coal gas flame, used with an ordinary blowpipe ("blow-through") jet, the oxygen being obtained from a cylinder of compressed gas; the oxy-hydrogen flame, both gases being obtained from cylinders, and being used either through a "blow-through" or a "mixing" jet; the oxy-ether flame, oxygen being obtained as before, and passed through a "saturator" containing ether in order to give the flame, pure

oxygen direct from the same cylinder being used to convert this into a blowpipe flame; the oxy-methylated spirit, where the spirit is fed to a small lamp, across which the oxygen is projected in the form of a jet; and lastly, the oxy-generator and ether-saturator arrangement, which has the merit of being a completely portable generating plant for both gases. Of all these the most generally selected is the oxy-coal gas arrangement with blow-through jet, as requiring least attention, least plant, and giving satisfaction in the hands of an amateur. For high-class apparatus projection the oxy-hydrogen mixed jet arrangement is the best, as a higher illumination is secured, but more gas is used, specially hard lines are required, and the installation is larger, more complex, and much more sensitive to small deficiencies of adjustment than the former system. The use of a "regulator" is recommended with compressed gases, as this allows the supply to be cut off at the lantern, without danger of blowing the connecting tube off the nipples.

Other illuminants may be considered unsuitable for the projection of apparatus.

2. *Condenser.*—The condenser used should never be less than 4″ diameter, and the makers may be trusted to supply the correct article in other respects. It should be readily accessible from the front, and admit of apparatus being placed close up to its front surface.

3. *Slide Carriers.*—Various slide carriers of excellent design are upon the market, that particularly recommended being Beard's patent "Eclipse" carrier, which may be worked from one side of the lantern, a point deserving of consideration.

4. *Objective.*—This should be of the "compound achromatic" type. No simple objective has yet given the author complete satisfaction, good definition of slides being only one desideratum; the objective should as accurately and clearly define the graduations of a burette as it does line diagrams upon slides.

Theoretically a single lens should perform this more satisfactorily than a compound one, owing to the thickness of the object projected, but this does not appear to be the case practically. For vertical cell work and similar purposes a single lens is sufficiently good, however.

Beyond this, the objective should be mounted so that adjustments are made by rack and pinion, and that horizontal and vertical alignment do not vary and require readjustment. A 6″ objective will be found generally most suitable in schools. It must be easily removable from the rest of the lantern, in order to

permit the substitution of microscope, polariscope, spectroscopic prism, etc.

5. *Erecting Prism.*—This is a right-angled prism, mounted immediately in front of the objective in such a way that the hypotenuse face is horizontal, and that the axis of the objective, produced, cuts the vertical line bisecting the right angle of the prism at a height of one-third from the hypotenuse face. It may be shown geometrically that only the lower two-thirds of an erecting prism is used, consequently any mounting other than that suggested will necessitate the lowering of the radiant during an erection. The hypotenuse face may with advantage be silvered. Tabulating the essential characteristics of a practical lantern, then, we have—

1. Interchangeable electric arc and limelight radiants.
2. Lantern body lined with fireproof material, and sufficiently large to permit all the various adjustments being made with ease. A cramped lantern body is a constant source of worry and annoyance to a demonstrator.
3. A condenser mounted so as to be accessible up to its front face.
4. A free space immediately in front of the condenser for tall apparatus.
5. Some reasonably solid supports for apparatus in front of condenser.
6. Compound achromatic objective properly shielded from stray light, and easily dismountable.
7. Mechanical fine adjustments for objective, and for horizontal and vertical motions of radiant.[1]
8. Free space between condenser and objective to admit apparatus.
9. Double stays for objective, in order to allow small platforms for apparatus such as a microscope or spectroscopic prism to be placed across the stays when the objective is removed.

For many years it has been almost impossible to purchase a lantern exhibiting all these essential points, and at a reasonable price—a price which would enable it to be purchased for general class-room use. The nearest approach was one placed upon the market by Messrs. Newton, of Fleet Street. It was fitted with arc lamp only, which was not interchangeable with limelight, and it had a single stay carrying the optical front. This, while

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[1] A perfectly serviceable method of horizontal adjustment is that of a screwed sector, mounted on a false base.

fairly rigid, could not be used as a support for small apparatus, and though two stays could be fitted if ordered, it was not a standard fitting In order to overcome many of these difficulties, and to introduce the possibility of vertical projections, Dr. Stroud and B. W. Rendall, Esq., of Leeds, jointly designed a lantern which gave great satisfaction in so far as the optical arrangements were concerned, but the body was cramped, and only limelight available as radiant.

Quite recently, however, a new lantern has been constructed by Messrs. Reynolds and Branson, Ltd., of Leeds, embodying the whole of the above-mentioned desiderata in a thoroughly practical lantern.

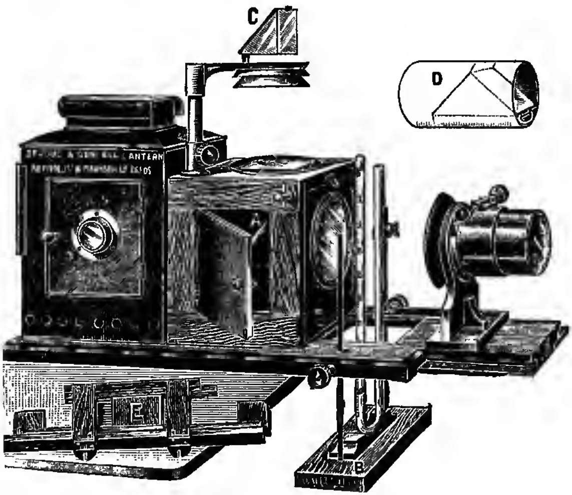


FIG. 118.—The new "Stroud and Rendall" lantern.

A, Mirror for use in vertical projection.

B, Table for holding tall apparatus (supporting rods may be used as retort stands for supporting glass tubes, etc., by means of suitable clamps).

C, Prism for deflecting vertical rays to screen.

D, Erecting prism, contained in tube fitting over objective.

E, Slide carrier.

It is improved out of all recognition, as compared with the older types, and is far ahead of any lantern known to the author and at present on sale.

It is possible with this lantern to show slides, vertically or horizontally, to project horizontal or vertical cells containing

liquids, to throw a continuous spectrum or a parallel beam upon the screen, to project ordinary microscope slides, polariscope work, galvanometer needles and scales, and is practically serviceable in every way required by the chemical, physical, and histological demonstrator. The lantern is illustrated herewith (Fig. 118); it is supplied at reasonable price, with limelight, or arc lamp fittings (or both), and is altogether satisfactory both from the point of view of prime cost and of convenience in working. Special tables and supporting rods are provided, while ample space for apparatus exists between condenser and objective, rendering the whole instrument compact, and specially suitable for general class-room, as well as lecture, demonstrations.

The actual projection of slides is attained by fixing the lantern upon a canting table, lighting up, and first centring the radiant, moving it horizontally and vertically until the screen is evenly illuminated. The carrier is then placed in position, a slide inserted, and the objective moved by the rough adjustments until a fairly clear image is formed upon the screen. The fine rack and pinion adjustment is then used to secure the best possible definition.

Lanterns without the fine adjustment for the objective should not be used, as the focus varies according to the thickness of the slide, and rough adjustments are not sufficiently steady to enable small variations of this character to be dealt with easily.

In the projection of apparatus, or cell work, little difficulty will be experienced if it be remembered that the objects projected should be as near as possible to the condenser. Slits for spectroscopic experiments may be cut from a sheet of copper, of such size as to fit the carrier-supporting device, cells may be made to a similar gauge, and apparatus suitable for projection always made to fit these devices. In this way a most valuable collection of projection apparatus will be gathered together, and the lantern above recommended is the only one known to the author, which, at a reasonable price, is capable of such development. Lanterns with a single rod carrying the objective and erecting prism should be avoided, as a single support does not permit of appliances of the microscope, or spectroscopic prism type being placed easily in position. Two supports are really necessary in order to secure comfort in rapid and varied demonstrations.

APPENDIX III

TABLES OF USEFUL DATA

Solubility of Salts in Water

Salt.	Weight in grams of salt dissolved in 100 grams water.		
	0° C.	20° C.	100° C.
Sodium chloride	35·7	36·0	39·7
Potassium chloride . . .	29·2	35·0	57·0
Ammonium chloride . . .	28·4	37·3	73·0
Barium chloride	—	42·2	72·0
Potassium bromide . . .	53·4	64·5	102·0
Potassium iodide	126·0	143·0	200·0
Potassium chlorate . . .	3·3	7·2	59·5
Potassium nitrate	13·3	31·7	246·0
Sodium nitrate	66·7	84·9	168·0
Calcium sulphate 2 aq. . .	0·2	0·25	0·5
Calcium sulphate (anhydr.).	0·2	0·24	0·21
Magnesium sulphate (cryst.)	26·2	35·3	73·5
Copper sulphate (cryst.) . .	31·6	42·3	203·3
Zinc sulphate (cryst.). . .	115·2	161·5	653·6
Potassium sulphate . . .	8·3	10·6	26·0
Potash alum (cryst.) . . .	3·3	15·4	357·5
Borax (cryst.)	2·8	7·8	200·0
Potassium bichromate . .	5·0	13·0	102·0
Sodium sulphate (anhydr.) .	4·5	20·0	43·0
Sodium sulphate (cryst.). .	12·1	58·3	212·4

	0° C.	20° C.	34° C.	37·5° C.	50° C.	100° C.
Sodium sulphate (cryst.). .	12·1	58·3	112·2	355·0	324·9	212·4

From Newth's "Chemical Lecture Experiments."

FUSION POINTS AND NOTABLE TEMPERATURES.

Table I.

Arranged according to temperature.

° C.		° F.	° C.		° F.
5000	Sun's estimated temperature	9000	103·7	Sea water boils	217·7
			100	Water boils	212
4000	Carbon melts	7232	79	Naphthalene melts	174
3500	Electric arc and acetylene - oxygen flame	6330	78·4	Ethylalcohol boils	173·1
			66·3	Methylalcohol boils	151·3
			63	Bromine boils	145·4
2800	Oxyhydrogen flame	5070	62–70	Beeswax melts	144–158
2500	Iridium and oxonium melt	4530	61·2	Chloroform boils	142·1
			60	Stearic acid melts	140
1870	Bunsen burner flame	3400	48	Carbon disulphide boils	118·4
1775	Platinum melts	3227			
1600	Wrought iron melts	2910	45–60	Paraffin wax melts	113–140
1400	White heat	2552	44	Phosphorus melts	111
1370	Steel melts	2500	42	Sheep fat melts	107
1275	Grey iron melts	2327	40	Ox fat melts	104
1200	Soft soda glass melts	2192	33	Butter melts	91
1083	Copper melts	1980	29	Palm oil melts	84
1050	White cast iron melts	1920	27	Lard melts	81
1000	Lead glass melts. Red heat	1832	17	Acetic acid melts	63
			0	Ice melts	32
960	Silver melts	1760	−7	Bromine solidifies	19·4
900	Brass and bronze melt	1652	−27	Turpentine solidifies	−16·6
			−39	Mercury solidifies	−38·2
800	Aluminium melts	1472	−40	F. and C. scales agree	−40
750	Magnesium melts	1382			
700	Dull red heat	1290	−55	Greatest antarctic cold	−67
419	Zinc melts	786			
400	Coal ignites	750	−75	Ammonia solidifies	−103
370	Paraffin boils	698	−169	Ethylene solidifies	−272·2
357	Mercury boils	674	−184	Oxygen liquefies (At ordinary pressure)	−299·2
327	Lead melts	620			
232	Tin melts	450	−192	Air liquefies (At ordinary pressure)	−313
179·5	Sat. sol. of calcium chloride boils	355	−193	Nitrogen and carbon monoxide liquefy (At ordinary pressure)	−315·4
156	Turpentine boils	313			
131·8	Amylalcohol boils	269·2	−252·5	Hydrogen liquefies (At ordinary pressure)	−422·5
120	Benzoic acid melts	248			
114	Sulphur melts	237	−257	Hydrogen solidifies	−430
113	Iodine melts		−273	Absolute zero	−459

FUSION POINTS AND NOTABLE TEMPERATURES.

TABLE II.
Arranged alphabetically.

° C.		° F.
17	Acetic acid melts	63
3500	Acetylene - oxygen flame	6330
−192	Air liquefies	−313
131·8	Alcohol (amyl) boils	269·2
78·4	Alcohol (ethyl) boils	173·1
66·3	Alcohol (methyl) boils	151·3
800	Aluminium melts	1472
−75	Ammonia solidifies	−103
−55	Antarctic cold	−67
62–70	Beeswax melts	144-156
120	Benzoic acid melts	248
900	Brass and bronze melt	1652
63	Bromine boils	145·4
−7	Bromine melts	19·4
1870	Bunsen burner flame	3400
33	Butter melts	91
179·5	Calcium chloride (sat. soln.) boils	355
4000	Carbon melts	7232
48	Carbon disulphide boils	118·4
−193	Carbon monoxide liquefies	−315·4
61·2	Chloroform boils	142·1
400	Coal ignites	750
1083	Copper melts	1980
700	Dull red heat	1290
3500	Electric arc	6330
−169	Ethylene freezes	−272
42	Fat (sheep)	107
40	Fat (ox)	104
1200	Glass (soft soda) melts	2192
1000	Glass (lead) melts	1832
−257	Hydrogen freezes	−430
−252·5	Hydrogen liquefies	−422·5
0	Ice melts	32
113	Iodine melts	235
2500	Iridium melts	4532
1275	Iron (grey) melts	2327
1050	Iron (white cast) melts	1920
1600	Iron (wrought) melts	2910
27	Lead melts	81
327	Lead melts	620
750	Magnesium melts	1382
357	Mercury boils	674
−39	Mercury freezes	−38·2
79	Naphthalene melts	174
−193	Nitrogen liquefies	−315·4
2500	Osmium melts	4530
−184	Oxygen liquefies	−299·2
2800	Oxyhydrogen flame	5070
29	Palm oil melts	84
45–60	Paraffin wax melts	113–140
370	Paraffin boils	698
44	Phosphorus melts	111
1775	Platinum melts	3227
1000	Red heat	1832
103·7	Sea water boils	217·7
960	Silver melts	1760
1370	Steel melts	2500
60	Stearic acid melts	140
114	Sulphur melts	237
5000	Sun's temperature	9000
232	Tin melts	450
156	Turpentine boils	313
−27	Turpentine solidifies	−16·6
100	Water boils	212
1400	White heat	2552
−273	Zero (absolute)	−430
419	Zinc melts	786

VOLUME AND DENSITY OF WATER FOR VARYING TEMPERATURES.

Temperature in degrees Centigrade.	Volume (vol. at 4° C. = 1)	Density in grams per 1 c.c.	Volume of 1 gram in c.c.
0	1·000129	0·999884	1·000116
1	1·000072	0·999941	1·000059
2	1·000031	0·999982	1·000018
3	1·000009	1·000004	0·999996
4	1·000000	1·000013	0·999987
5	1·000010	1·000003	0·999997
6	1·000030	0·999983	1·000017
7	1·000067	0·999946	1·000054
8	1·000114	0·999899	1·000101
9	1·000176	0·999837	1·000163
10	1·000253	0·999760	1·000240
11	1·000345	0·999668	1·000332
12	1·000451	0·999562	1·000438
13	1·000570	0·999443	1·000557
14	1·000701	0·999312	1·000688
15	1·000841	0·999173	1·000828
16	1·000999	0·999015	1·000986
17	1·001160	0·998854	1·001147
18	1·001348	0·998667	1·001335
19	1·001542	0·998473	1·001529
20	1·001744	0·998272	1·001731
21	1·001957	0·998060	1·001944
22	1·002177	0·997839	1·002164
23	1·002405	0·997614	1·002392
24	1·002641	0·997380	1·002628
25	1·002888	0·997113	1·002875
26	1·003144	0·996879	1·003131
27	1·003408	0·996616	1·003395
28	1·003682	0·996344	1·003669
29	1·003965	0·996064	1·003952
30	1·004253	0·995778	1·004240
40	1·00770	0·99236	1·007682
50	1·01195	0·98821	1·011928
60	1·01691	0·98339	1·016906
70	1·02256	0·97795	1·022542
80	1·02887	0·97195	1·028856
90	1·03567	0·96557	1·035662
100	1·04312	0·95866	1·043117

"Physikalisch—Chemische Tabellen," Randolt und Börnstein.

DENSITIES OF COMPOUNDS, ETC.

Acetic acid	1·05	Coal (bituminous)	1·29	Ivory	1·92
Agate and rock crystal	2·6	Cork	0·24	Lard	0·94
Air	0·00129	Diamond	3·5	Lignum vitæ	1·3
Alcohol (amyl)	0·815	Earth (mean)	5·53	Linseed oil	0·931–0·938
Alcohol (ethyl)	0·795	Ebony	1·19	Mahogany	0·56–0·85
Alcohol (methyl)	0·796	Elm wood	0·544	Marble	2·5
Aluminium bronze	8·0	Emerald	2·7	Milk (cow's)	1·03
Amber	1·1	Emery	4·0	Oak wood	0·69–0·99
Anthracite	1·5	Ether (ethyl)	0·716	Olive oil	0·915
Ash wood	0·753	Galena	7·6	Oxidised oils	0·967–1·00
Bamboo	0·4	Glass (bottle)	2·64	Petroleum	0·84–0·88
Beech wood	0·69–0·8	Glass (crown)	2·5	Pine wood	0·56
Benzene	0·88	Glass (flint)	3–3·6	Pumice	2·2–2·5
Bitumen	0·8–1·2	Glass (Faraday's)	4·36	Ruby	3·6–4
Blood (human)	1·06	Glycerine	1·26	Sand	1·42
Boxwood	0·96	Gold alloy (18 carat)	14·88	Sea water	1·026
Bone	1·8–2·0	Gold alloy (mint)	17·49	Silver (mint)	0·38
Brass	7·6–8·3	Granite	2·7	Spermaceti	0·94
Brick	2·1	Graphite	2·2	Starch	1·53
Bronze (84 Cu, 16 Sn)	8·56	Gun-metal	8·5	Sugar (cane)	1·6
Bronze coinage	8·66	Gutta-percha	0·97	Suet	0·92
Carbon disulphide	1·27	Human body (mean)	1·07	Teak	0·8
Chalk	2·0	Iceland spar	2·7	Turpentine	0·87
Chestnut wood	0·535	Indiarubber	0·79	Wax (bees')	0·96
Chloroform	1·526	Iron (cast)	7·2	Willow wood	0·4
Cinnabar	8·1	Iron (wrought)	7·79	Wool	1·61
Clay	1·92	Iron (steel)	7·79		

PHYSICAL CONSTANTS OF THE ELEMENTS.

Element.	Symbol.	Atomic weight O = 16·00 A	Specific heat. S	Atomic heat. A × S	Specific gravity.	Melting point (° C.)	Coefficient of linear expansion.
Hydrogen	H	1·008	6 (?)	6	—	−257°	—
Helium	He	4·0	—	—	—	−271°	—
Lithium	Li	7·03	0·941	6·61	0·59	180°	—
Glucinum	Gl	9·1	0·621	5·64	2·07	B.R.H.	—
Boron	B	11·0	0·5	5·5	2·6	—	—
Carbon	C	12·00	0·459	5·50	3·52	—	0·0000078
Nitrogen	N	14·01	—	—	0·808	−214°	—
Oxygen	O	16·00	—	—	1·203	−225°	—
Fluorine	F	19·0	—	—	—	−223°	—
Neon	Ne	20	—	—	—	−252°	—
Sodium	Na	23·05	0·290	6·68	0·97	95°	0·0000710
Magnesium	Hg	24·36	0·250	6·09	1·74	632°	0·0000269
Aluminium	Al	27·1	0·218	5·91	2·56	657·3°	0·0000231
Silicon	Si	28·4	0·203	5·76	2·49	2660°	0·0000076
Phosphorus	P	31·0	0·190	5·89	1·83	44°	0·000012
Sulphur	S	32·06	0·177	5·67	2·05	114°	0·0000641
Chlorine	Cl	35·45	—	—	1·51	−102°	—
Potassium	K	39·15	0·170	6·65	0·87	62°	0·0000841
Argon	A	39·9	—	—	1·39	−189·6°	—
Calcium	Ca	40·1	0·170	6·82	1·55	800°	—
Scandium	Sc	44·1	0·153	6·74	—	—	—
Titanium	Ti	48·1	—	—	—	—	—
Vanadium	V	51·2	0·125	6·40	5·5	1680°	—
Chromium	Cr	52·1	0·120	6·25	6·80	V.H.	—
Manganese	Mn	55·0	0·120	6·60	8·00	1245°	—
Iron	Fe	55·9	0·110	6·15	7·86	1600°	0·0000121
Nickel	Ni	58·7	0·108	6·34	8·80	1480°	0·0000127
Cobalt	Co	59·0	0·103	6·08	8·80	1530°	0·0000123
Copper	Cu	63·6	0·093	5·91	8·93	1083°	0·0000167
Zinc	Zn	65·4	0·094	6·15	6·92	419°	0·0000291
Gallium	Ga	70	0·079	5·53	5·9	30°	—
Germanium	Ge	72·5	—	—	—	900°	—
Arsenic	As	75·0	0·081	6·07	5·67	—	0·0000055
Selenium	Se	79·2	0·080	6·34	4·50	217°	0·0000368
Bromine	Br	79·96	0·084	6·72	3·2	−7°	0·00035
Krypton	Kr	81·8	—	—	2·15	−147°	—
Rubidium	Rb	85·5	—	—	1·52	38·5°	—
Strontium	Sr	87·6	—	—	2·5	800°	—
Yttrium	Yt	89·0	—	—	3·80	—	—
Zirconium	Zr	90·6	0·066	5·98	4·08	1500°	—
Columbium	Cb	94	—	—	4·06	1950°	—
Molybdenum	Mo	96·0	0·072	6·91	8·6	2500°	—
Ruthenium	Ru	101·7	0·061	6·20	12·26	1800°	0·0000096
Rhodium	Rh	103·0	0·058	5·97	12·10	2000°	0·0000085

Element.	Symbol.	Atomic weight O = 16·00 A	Specific heat. S	Atomic heat. A × S	Specific gravity.	Melting point (°C.)	Coefficient of linear expansion.
Palladium . .	Pd	106·5	0·059	6·28	11·50	1587°	0·0000117
Silver . . .	Ag	107·93	0·056	6·04	10·49	962°	0·0000192
Cadmium . .	Cd	112·4	0·056	6·29	8·65	321·7°	0·0000306
Indium. . .	In	115	0·057	6·55	7·42	176°	0·0000070
Tin	Sn	119·0	0·055	6·54	7·29	232°	0·0000223
Antimony . .	Sb	120·2	0·050	6·01	6·62	630·5°	0·0000105
Iodine . . .	I	126·97	0·054	6·85	4·93	114°	0·000235
Tellurium . .	Te	127·6	0·049	6·25	6·20	525°	0·0000167
Xenon . . .	Xe	128	—	—	3·52	—	—
Cæsium . .	Cs	132·9	0·048	6·38	1·88	26·37°	—
Barium . .	Ba	137·4	—	—	3·78	850°	—
Lanthanum .	La	138·9	0·045	6·25	6·15	810°	—
Cerinm . .	Ce	140·25	0·045	6·31	7·04	623°	—
Praseodymium	Pr	140·5	—	—	6·47	940°	—
Neodymium .	Nd	143·6	—	—	6·96	940°	—
Samarium . .	Sm	150·3	—	—	7·7	—	—
Europium . .	Eu	152	—	—	—	—	—
Gadolinium .	Gd	156	—	—	—	—	—
Terbium . .	Tb	159·2	—	—	—	—	—
Erbium . .	Er	166	—	—	4·77	—	—
Thulium . .	Tm	171	—	—	—	—	—
Ytterbium . .	Yb	173·0	—	—	—	—	—
Tantalum . .	Ta	181	0·036	6·51	16·64	2250°	0·0000079
Tungsten . .	W	184	0·034	6·26	18·7	2500°	—
Osmium . .	Os	191	0·031	5·92	22·48	2500°	0·0000065
Iridium . .	Ir	193·0	0·033	6·37	22·42	2500°	0·0000070
Platinum . .	Pt	194·8	0·032	6·23	21·50	1775°	0·0000089
Gold . . .	Au	197·2	0·031	6·11	18·88	1066·0°	0·0000144
Mercury . .	Hg	200·0	0·032	6·40	13·59	−39°	0·0000610
Thallium . .	Tl	204·1	0·033	6·73	11·85	288°	0·0000302
Lead . . .	Pb	206·9	0·031	6·41	11·34	326·9°	0·0000292
Bismuth . .	Bi	208·0	0·031	6·45	9·78	268°	0·0000162
Radium . .	Rd	225	—	—	—	—	—
Thorium . .	Th	232·5	0·028	6·51	11·10	V.H.	—
Uranium . .	U	238·5	0·028	6·68	18·70	B.R.H.	—

FREEZING MIXTURES.

	Ingredients.	Parts by weight.	The thermometer sinks ° F.	Diminution of temperature.
1	Water Ammonium nitrate	1 1	From +40° to + 4°	36° Fahr.
2	Water Potassium nitrate Ammonium chloride	16 5 5	,, +50° to +10°	40° ,,
3	Water Ammonium nitrate Carbonate of soda	1 1 1	,, +50° to − 7°	57° ,,
4	Snow Sodium chloride	2 1	,, +32° to − 5°	37° ,,
5	Snow Crystallised calcium chloride	2 3	,, +32° to −50°	82° ,,
6	Crystallised sodium sulphate Hydrochloric acid	8 5	,, +50° to 0°	50° ,,

From "Scientists' Pocket Book and Diary," Messrs. Woolley & Co., Manchester.

LATENT HEATS.

Fusion.		Vaporization.	
Beeswax	97·22	Acetic acid	102·0
Bismuth	12·64	Alcohol (ethyl)	209·0
Bromine	16·18	Alcohol (methyl)	264·0
Cadmium	13·55	Bromine	45·6
Ice	79·25	Carbon disulphide	86·7
Iron (grey cast)	23·00	Chloroform (at 100° C.)	80·7
Lead	5·86	Ether	91·0
Mercury	2·82	Formic acid	168·0
Phosphorus	5·40	Mercury	62·0
Platinum	27·18	Sulphur	362·0
Silver	21·07	Turpentine	69·0
Spermaceti	82·22	Water	536·0
Sulphur	9·37		
Tin	14·25		
Zinc	28·13		

From various sources.

SOLDERS COMMONLY IN USE.

Material to be soldered.	Composition of solder in parts by weight.			M.P. of solder in °C.	Most useful flux.
	Lead.	Tin.	Bismuth.		
Lead . . .	1	1	—	188	Tallow
Brass, copper, etc.	3	5	—	176	Neutral zinc chloride solution or resin (for electrical work)
Zinc	3	5	—	176	Zinc chloride solution +25 per cent. free HCl
Pewter . . .	2	1	2	113	Tallow
Iron	2	5	—	170	Sal ammoniac solution

This latter solder makes excellent blowpipe solder, particularly with the addition of 5 per cent. bismuth.

Memoranda

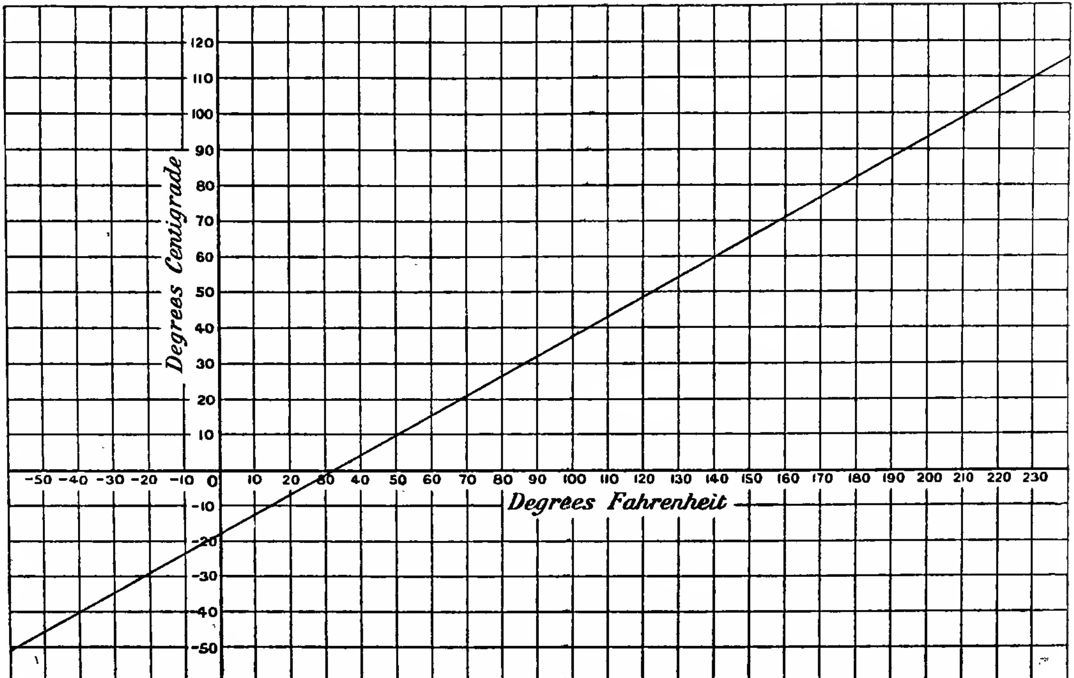
Memoranda

Memoranda

Memoranda

Memoranda

Memoranda



Graph for the conversion of temperatures.

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THE END

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